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The Utilization of Blast-Furnace Gases for Power Purposes.

BY CHARLES KIRCHHOFF,
Honorary Member of the Institute.

A splendid example of the co-operation of different branches of engineering is furnished by the recent development in the utilization of waste blast-furnace gas for power purposes. The metallurgist has adapted himself to the requirements of the mechanical engineer, while the latter has worked out the problem of using a gas of low thermal value in large units of internal combustion engines, the electrical engineer stepping in through the concentration of power development by electrical transmission to isolated installations.

The fact that the blast furnace is nothing more than a huge gas producer was realized long ago, and it was one of

the long steps in the direction of a more complete utilization of the fuel charged into the furnace when the system of heating the blast and of producing steam for the blowing engines was introduced. But for generations progress was confined to improvements in the design and construction of hot-blast stoves and of boilers and blowing engines, although some metallurgists, notably Luermann, urged that there was much room for further economies, since the calorific capacity of waste blast-furnace gas was far from being effectively utilized. How inadequate the prevailing methods were is proven by the fact that a good deal of coal was burnt at blast-furnace plants in order to cover their own requirements.

In the meantime the gas engine, first employed exclusively in small units and with illuminating gas, invaded new fields, and successfully grew in size. Builders learned to use producer gas and built larger and larger units, until finally Delamare Debouteville brought out the Simplex gas engine, which was adopted by the Société Cockerill at Seraing, Belgium, whose engineers had begun the study of the subject in 1895. A year earlier, however, B. H. Thwaite, an Englishman, had urged the use of blast-furnace gas for driving gas engines, and he must probably be regarded as the pioneer in this field. The Simplex engine had been running on poor producer gas, and experiments first began at Seraing, with a 4-horse-power engine of that type, changed later to an 8-horse-power engine. Later still M. Delamare Debouteville was instructed to design a 150-horse-power engine, which was started in the spring of 1898. Then came the famous Cockerill engine of 600 horse-power at the Paris Exposition, which focussed the attention of iron-masters upon the subject. In the meantime experiments had been carried on at Hoerde, in Westphalia, and the Germans took hold of the problems involved very vigorously.

In our own country development has been along somewhat different lines. The utilization of waste furnace gas had been neglected, and even now many of our leading furnacemen maintain an attitude of reserve. The only exception is Mr. Henry Wehrum, chief engineer of the Lackawanna

Steel Company, who is putting in three plants, one of eight 1,000-horse-power engines to drive dynamos and two others of together sixteen 2,000-horse-power engines, which are to drive blowing engines, the whole installation to be a part of the great new steel plant at Buffalo.

In this country, the large unit gas engine has been developed by Westinghouse, and particularly by E. C. Luffkin, of the Snow Steam Pump Works, who has used them exclusively for pumping natural gas and being operated by the same. The Standard Oil Company has, during the past few years, gone extensively into the collection and distribution of natural gas and has, for instance, laid down lines from West Virginia to Cleveland and a number of Ohio interior towns. It is understood that there are now practically completed two gas engines of 4,000-horse-power, which are being installed for this service at Cleveland.

One of the reasons why American engineers have been so slow to use furnace gas is that, particularly in all the districts in which Lake Superior ores are used, the gases are laden with the dust from the fine Mesaba ores.

How rapidly the use of blast-furnace gas engines has spread is shown by a compilation made in the fall of 1902 by Herbert A. Humphrey, who has a list of engines in Europe and the United States of over 200-horse-power. He enumerates 327 engines capable of supplying 181,605 horse-power. This does not include many more recent installations, so that to-day there are probably built or building 225,000 horse-power of large gas engines, of which by far the greater number operate with blast-furnace gas.

There is every reason to believe that this is really only the beginning of a movement which will culminate in supplying a very large amount of power, to be used either to operate the machinery of adjacent steel works, rolling mills or factories, or to be employed in making calcium carbide or other electrometallurgical products. Some conception of the magnitude of this hitherto wasted energy may be gathered from the following figures: Assuming, as we have a right to do, that 25 per cent. of the heat energy of the gas can be realized in effective power, there is available, after

deducting the requirements of the furnace plant, at least 800 horse-power for every ton of iron produced per hour.

At the present output in the United States, of 19,500,000 tons per annum, we are making 2,250 tons per hour, or have an available surplus of 1,800,000 horse-power. At as low a rate as $15 per horse-power per annum, this country, if its blast furnaces were equipped with gas engines, would save $28,800,000. Or, putting it in another way, a modern furnace producing 500 tons of iron per day would, at $15 per horse-power, save $250,000 per annum, which on its cost of about $1,000,000 would pay for very liberal depreciation and renewals and leave a handsome dividend. Of course, only the first-comers could hope to secure such revenues, since when the use of gas engines became general, competition would soon lead to a corresponding reduction in prices. In many cases the character of the coal being coked would place at the disposal of the furnace manager an additional surplus of power. At one great plant in this country preliminary computation showed that in coking the coal at the works in by-product ovens the steam required for the rolling mills might be covered from its waste gases, and that then nearly 49,000 horse-power would be for sale, which, at $16 per horse-power, would realize $775,000 per annum. The utilization of the waste gases is therefore a matter of the keenest interest to the iron maker, and holds out the promise of brilliant rewards.

It would take us altogether too far to follow in detail the computations by which closely accurate data relative to the quantity and quality of the waste furnace gas can be arrived at. Mr. E. A. Uehling has presented figures in an interesting paper published in the *Stevens Indicator*. But some of the principal data may be presented which summarize the results of an investigation made by Mr. Henry Wehrum, of the Lackawanna Steel Company, who took as the basis Lake ores of well-determined composition. The total charge per ton of iron consists of 1·56 tons of ore, 0·33 ton of flux, 0·85 ton of fuel and 3·55 tons of blast, a total of 6·31 tons. The products are 1 ton of pig iron carrying 3·5 per cent. of carbon, 1·0 per cent. of silicon, and 0·06 of phosphorus.

The slag amounts to 0·37 ton carrying 33 per cent. of silica, while the total weight of the gas per ton of pig iron would amount to 4·942 tons. In other words, for each ton of pig iron produced there escapes from the furnace nearly five times the weight of gas. This would carry, by volume, 23·77 per cent. of carbonic oxide, 14·74 per cent. of carbonic acid, 59·45 per cent. of nitrogen, 1·72 per cent. of hydrogen, 0·03 per cent. of water, and 0·27 per cent. of methane. There is available from this gas, by combustion with 20 per cent. excess of air per ton of pig iron made, 11,200,000 British thermal units, or 4,800 horse-power. Mr. Uehling figures that it requires 1,932,067 thermal units, or 750 horse-power, to heat the blast per ton of pig iron to 1,200°, which, with 5 per cent. allowance for leakage, would require 1,884 pounds of gas. This leaves about 4,000 horse-power in surplus gas, or, assuming an efficiency of 25 per cent. for the gas engines, about 1,000 horse-power. From this must be deducted about 200 horse-power to operate blowing engines, pumps, the apparatus for handling materials, lighting, etc., and there is left for sale or for other useful work 800 horse-power for every ton of iron produced per hour.

As already stated, in the old method of burning the gas under boilers and driving the machinery with steam, it took all the gas and sometimes even additional fuel to do the work. The substitution of internal combustion engines for the roundabout method through a boiler and steam-engine plant made available the large surplus referred to, which we may even hope to increase as the efficiency of the gas engines improves. Calculations are now on the basis of 25 per cent. efficiency. Actual tests show a record of 38 per cent. in the case of a Koerting double acting two-cycle engine.

A natural use to which this surplus power is put in many iron works is to drive a part of the steel works and rolling-mill machinery, the blast furnace being often an integral part of the plant. It is here that progress in another direction co-operates effectively. During the past ten years the isolated units of power plant scattered formerly over steel works and rolling mills have been concen-

trated in electric central stations, with a very great resultant saving of the losses in transmission. One of the first uses to which furnace-gas engines has been put is that of driving dynamos, the original obstacles to producing the alternating current in parallel having been overcome. In 1900 I had occasion to visit the Differdingen plant in Lorraine, when the installation of a plant of nine 600-horse-power furnace-gas engines was being completed. Mr. Max Meyer, the general manager, then informed me that the engines driving dynamos direct would supply power enough to operate all the machinery in the steel plant and rolling mill with the exception of the Bessemer blowing engine and those for driving the blooming mill and the large beam mill.

Some of the optimists among our engineers claim that the time will come when no steam whatever will be raised in a plant producing rolled shapes from the ore and coal up, particularly if the latter is of such a character that there is a surplus of gas from the coking operation. Of course, this means that for some of the heavy trains, like the blooming mills, enormous internal combustion engines must be provided. That, however, does not seem to frighten the enthusiasts, and I have been told that mechanical engineers are even now designing blast-furnace gas engines to develop 5,000 horse-power. One of the difficulties which suggests itself is that of coupling gas engines with roll trains, subject to such wide and sudden fluctuations in power requirements. So far as the lighter roll trains are concerned, experience in Germany has already justified the expectations of those who are blazing a new path in this branch of iron manufacture.

From a metallurgical point of view, the one difficulty which soon presented itself was the question of ridding the furnace gas not alone of the coarser dust, a part of which is caught in the dust-catcher, but also of the fine fumes which coat and corrode the engine ports and cylinders. At first the experience at Seraing seemed to indicate that this would not involve serious inconvenience, but as the gas engines found a place in other plants, it was realized that the importance of thoroughly cleaning the gas is great.

Incidentally it has become clear that it will pay to wash the gas which is used to heat the blast, because dust is kept out of the hot-blast stoves, whose efficiency is thus greatly enhanced, and whose life is thus considerably extended. A gas-cleaning plant has thus become a part of every installation.

Two methods have been pursued to get rid of the dust. One is to utilize the effect of a change in the velocity of the air current by alternate constriction and enlargement of the pipes, often combined with a moistening of the dust. This is termed the static method. The other, called the dynamic method, is to drive the gas through sprays of water. Conspicuous among these is the Theisen centrifugal purifier, in which the gases are driven around a rapidly-revolving cylinder, equipped with vanes. The interior surface of the casing is covered with wire gauze. Filtration through columns of coke or of sawdust has been employed, as at Oberhausen. Fans with water-spray have been adopted in different ways, as at Differdingen, Dudelingen, by Lencauchez at Micheville, and by Capell at Ormsby. Le Tombe at Marseilles has introduced an intermediary between the Theisen system and the fan, and at Eschweiler a static electrical system has been tried, depending on the cohering effect on suspended dust particles of static electricity. It is claimed that it has produced excellent results. Generally speaking, managers have been adequately successful in getting rid, not only of the heavier dust, but also of the light fumes, which it was more troublesome to deal with. In Europe the dust evil is now quite generally regarded as overcome, but it must not be forgotten that the trouble is not as serious as it is likely to be with us.

Now as to the gas engines themselves. The earlier types were the Simplex, designed by Delamare-Debouteville, which has been modified by the engineers of the Cockerill Company and the Koerting, first put in at Hoerde. This engine is now being built in the United States by the De la Vergne Refrigerating Machine Company, of New York, while the Allis-Chalmers Company have quite recently

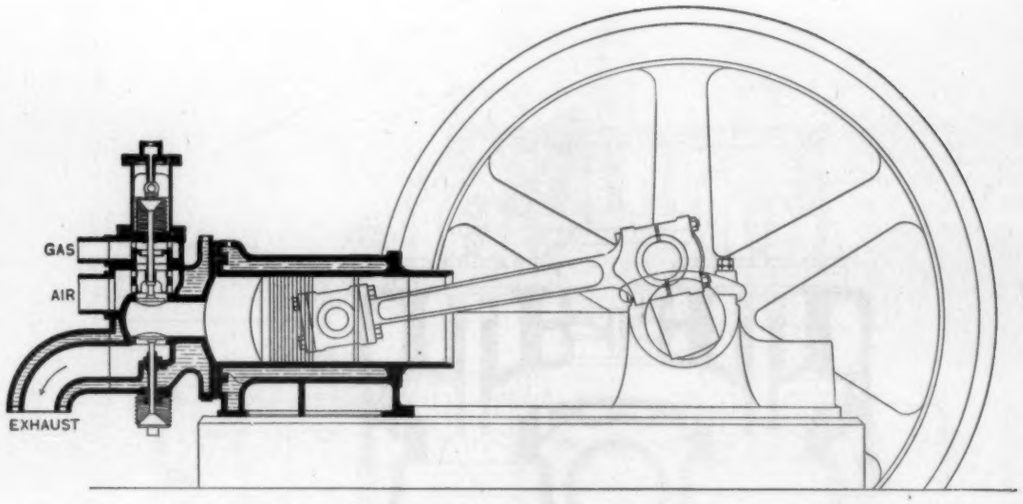
become the licensers of the Augsburg and Nürenberg Company. According to the testimony of German engineers this more recent design has been doing exceptionally effective work.

There has been a very eager struggle for improvement in the design of large unit internal combustion engines during the past few years, and some of the most famous of the great steam-engine builders are engaged in it, since the field is very large. As a matter of fact, the utilization of waste furnace gas is only a part, and possibly only a small part, of it. It has been thoroughly proven that important economies can be effected by gasifying coal and using internal combustion engines over the old method of burning the same fuel under boilers and using steam engines. The ordinary gas producer, the Mond process, with recovery of ammonia, and the Pettibone-Loomis process, are being rapidly introduced, so that the gas engine is forging ahead for central station work, for pumping plants and miscellaneous power installations.

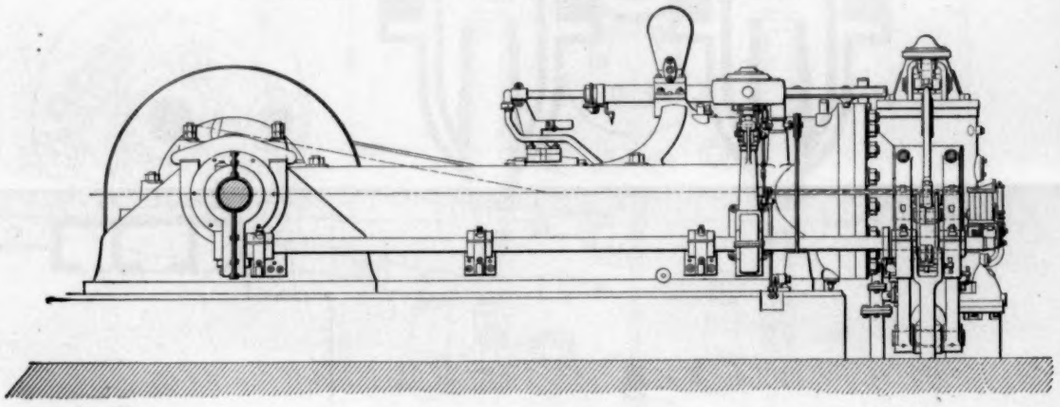
The function of the gas engine is to convert into power the impulse of an explosion of a mixture of fuel gas and air. With the poorer gases it is necessary to compress them first before satisfactory ignition and combustion can be effected. We have then the drawing or forcing into the engine cylinder of a mixture of gas and air, its compression to the required point, the ignition of the gas, and after the completion of the stroke, the expulsion of the gases of combustion. So far as the machine itself is concerned, certain considerations must guide in its design. As the result of the explosion there is a marked rise in the temperature, which might prove dangerous to the life of the engine. Elaborate cooling is therefore necessary, and the parts must be so designed that they do not suffer from temporary exposure to hot gases.

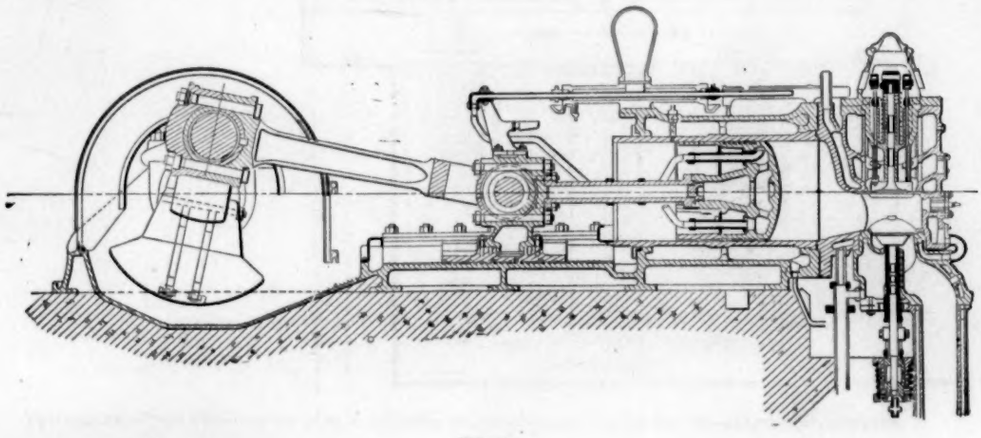
Permit me to present some of the principal engine designs, beginning first with the ordinary four-cycle or Otto-cycle engines, of which the Deutz engine is a good example. (Plate I.)

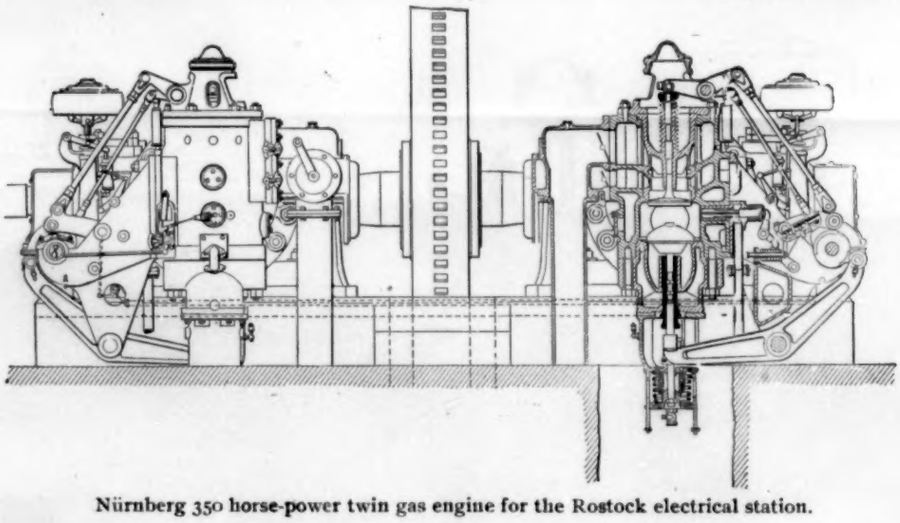
The latest Deutz design of governing gear is indicated.



Single-acting Deutz 4-cycle gas engine. Longitudinal section.



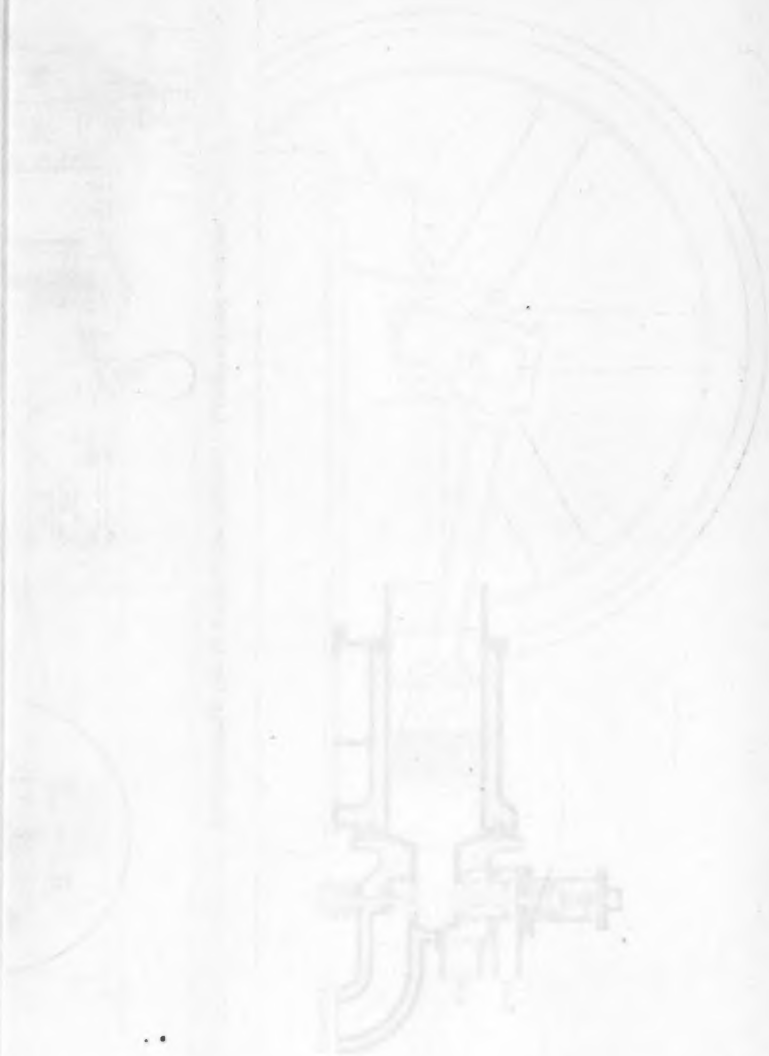


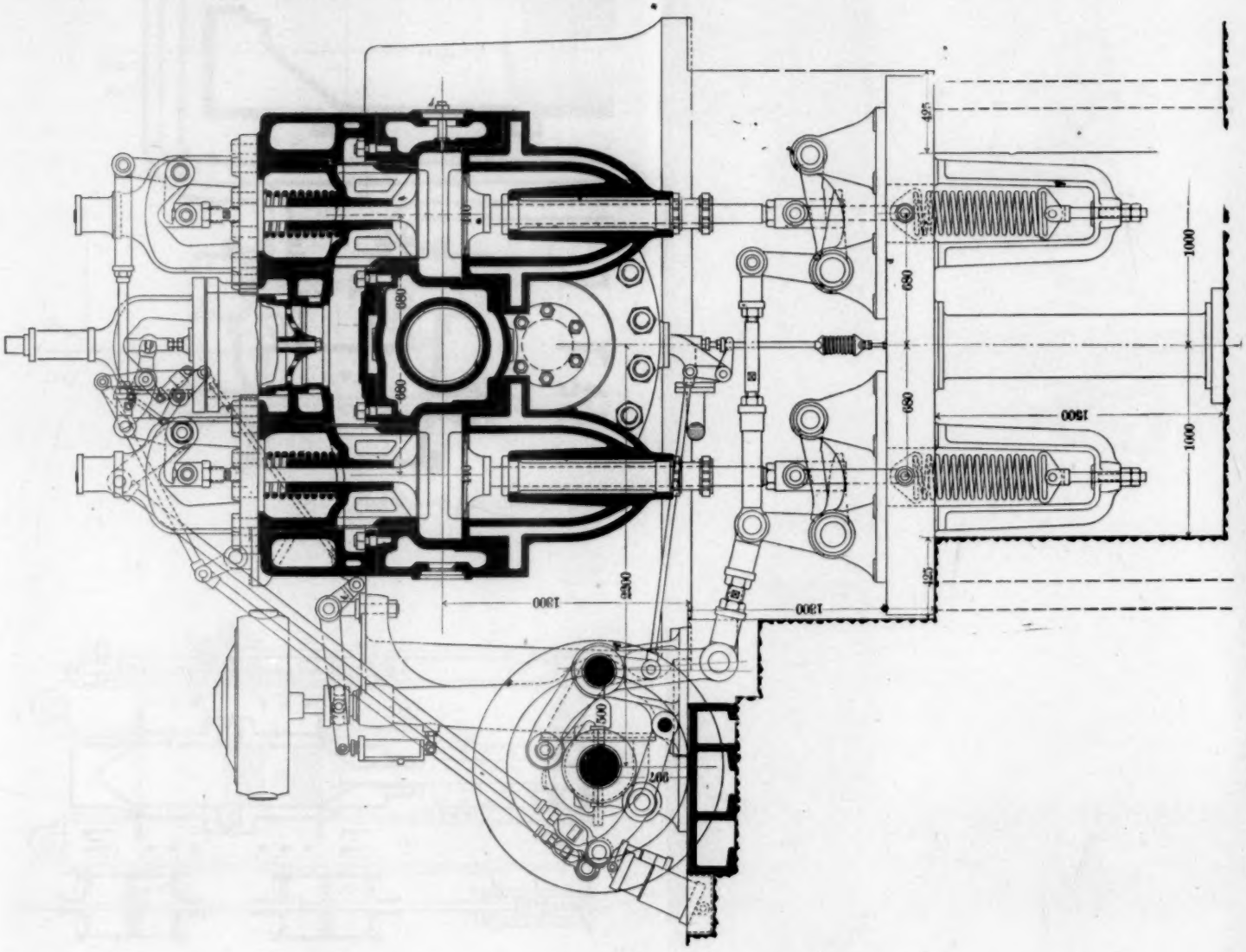


Nürnberg 350 horse-power twin gas engine for the Rostock electrical station.

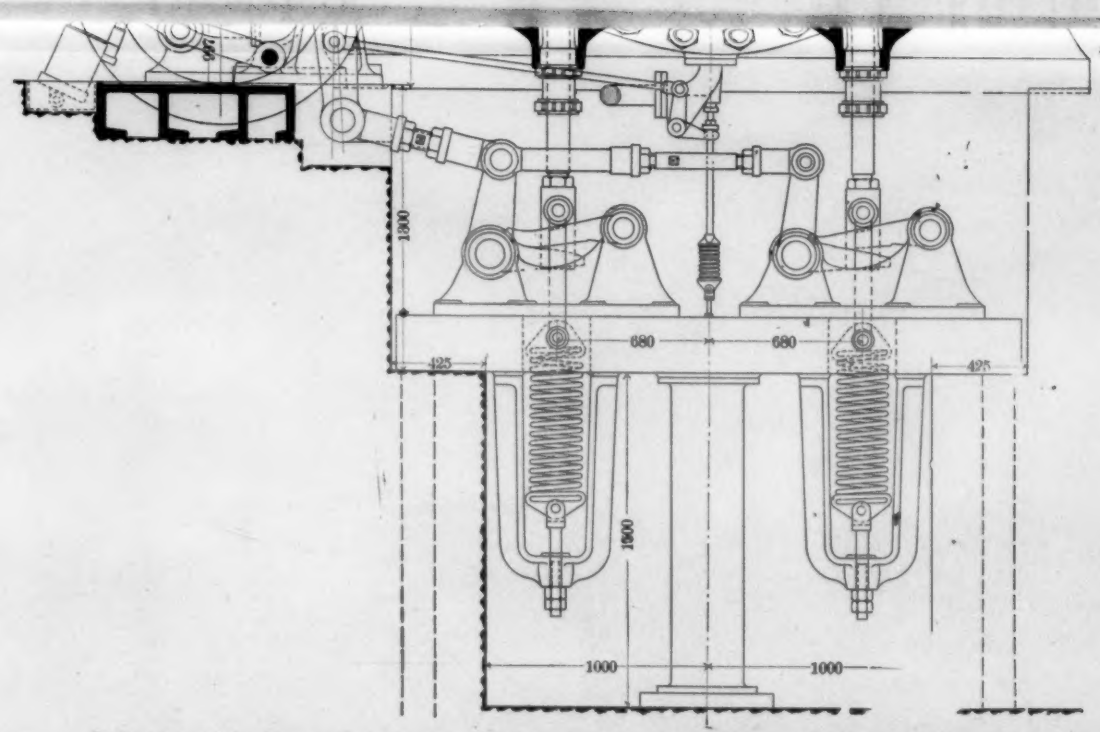
PLATE I.—TYPES OF BLAST FURNACE GAS ENGINES.

(Kirchhoff.)





Valve-gear of 750 horse-power single-cylinder Nürnberg gas engine for Rheinische Stahlwerke.



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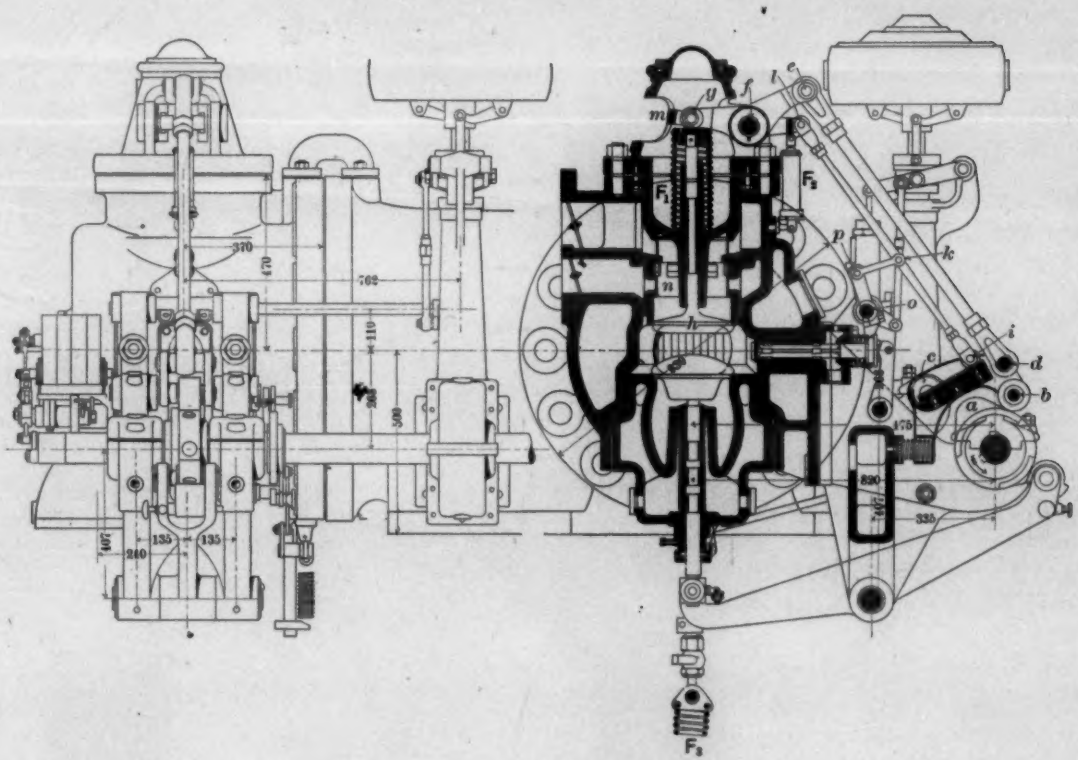
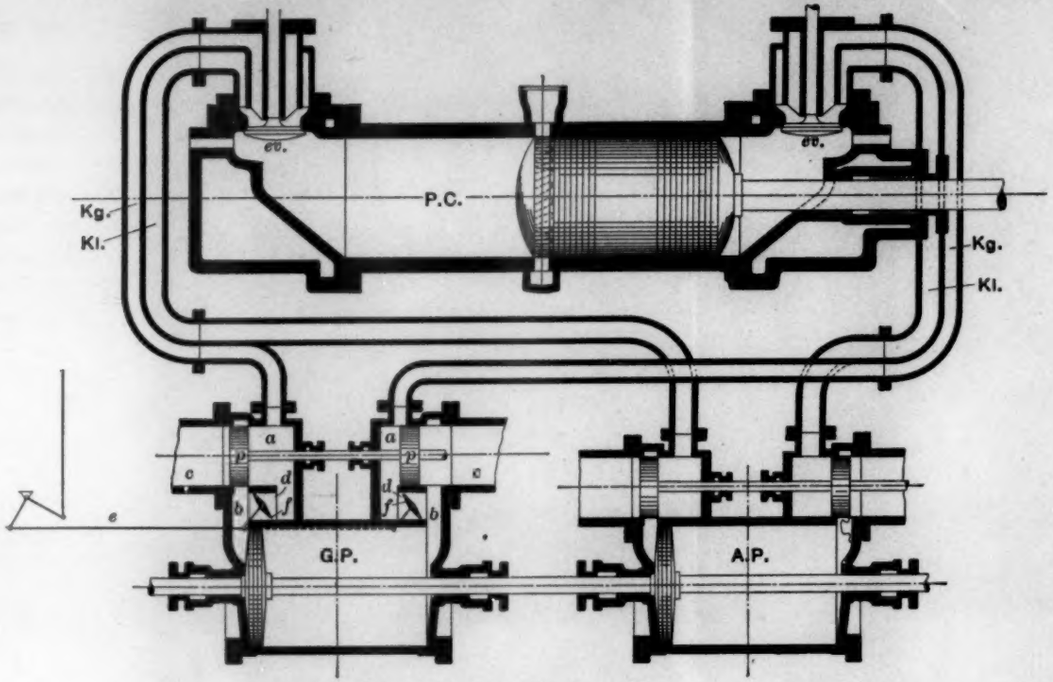


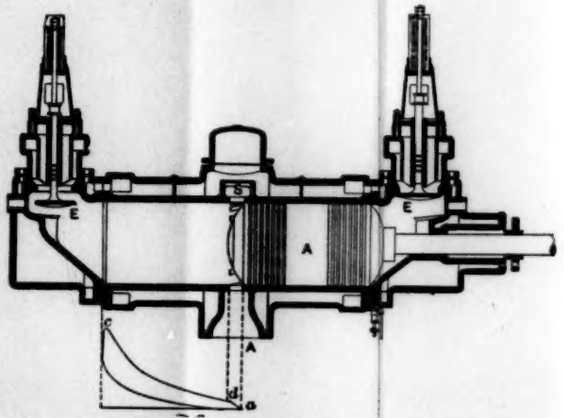
The new gear of the Nürnberg Company.

PLATE II.—NÜRNBERG COMPANY'S VALVE GEAR.

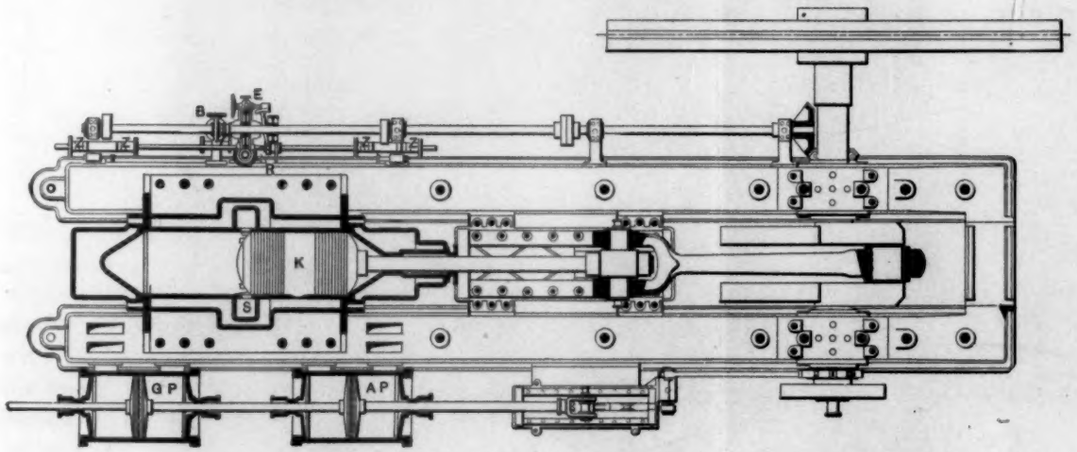
(*Kirchhoff.*)



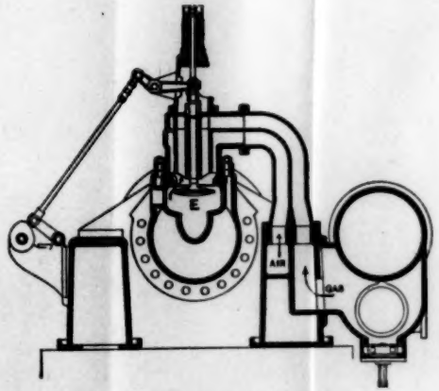
Plan showing method of working.



Longitudinal section through working cylinder.



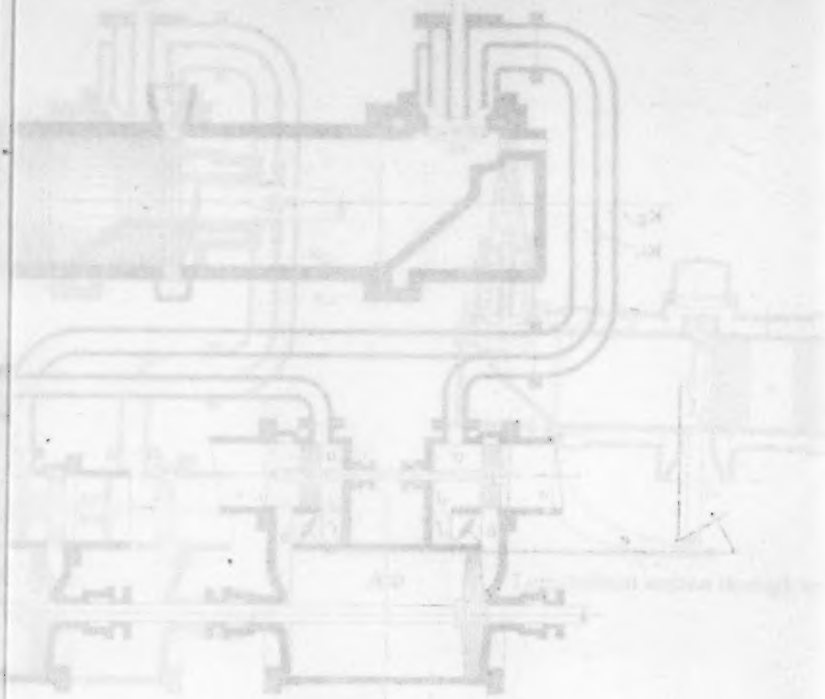
Horizontal section.

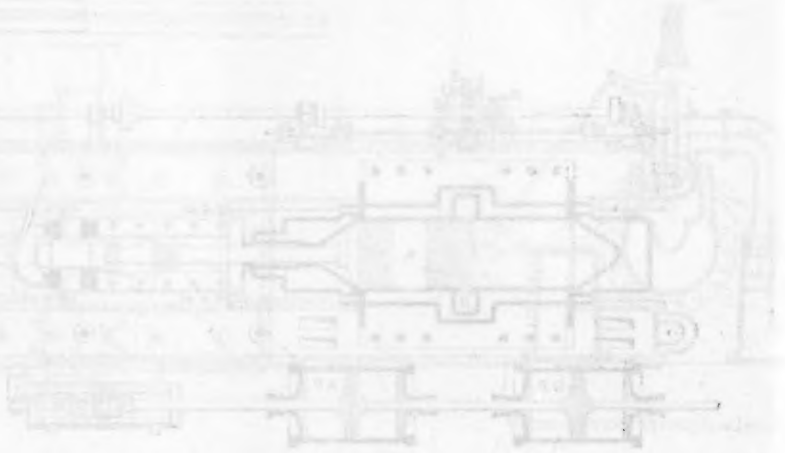


Cross-section through admission valve.

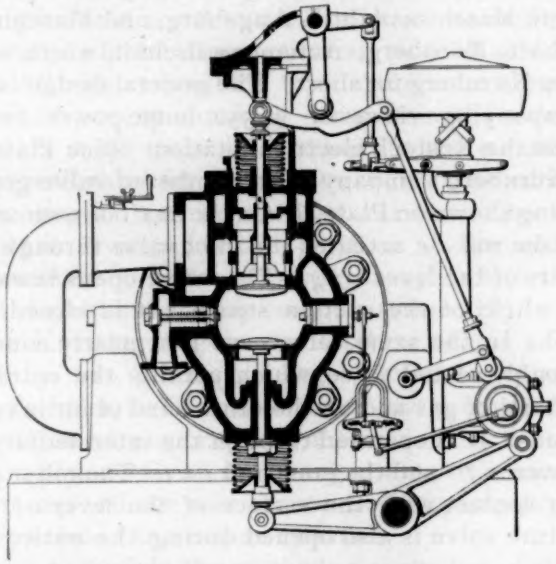
P, piston in working cylinder; *S*, exhaust ports; *G P*, gas pump; *A P*, air pump; *E*, adjustment device for igniter; *B*, valve for admission of compressed air for starting engine.

PLATE III.—KOERTING DOUBLE-ACTING, 2-CYCLE GAS ENGINE.





The gas and the inlet valve are combined with a piston valve for the admission of air in the same casing and are mounted on the same spindle. When the valve spindle is pressed down by the gear mechanism, the inlet is first opened and the air valve and the gas valve follow a moment later, opening inward or downward. A powerful spring closes them. One end of the valve lever is attached to the valve spindle, the other end seizes a rod driven from the gear shaft. The support of the valve lever is a roller.



Single-acting Deutz 4-cycle gas engine. Section through cylinder head.

When the driving rod is lifted, the valve lever presses against the roller and the inlet valve is forced downward. When the driving rod descends, the valve is gradually closed. The arrangement is so made that the valve opens with the beginning of the suction stroke and closes toward the end of that stroke. The roller is borne by a lever which oscillates on a shaft acted upon by the governor, and the valve lever is so shaped and so arranged that its upper surface, when the valve is closed, forms a circle tangential to the roller circumference, the center being the center of the

shaft operated by the governor. When the governor by a turn of the shaft changes the position of the roller, the valve is kept open for the same period of time as before, only it is opened more or less. The regulation, therefore, amounts to throttling the supply of gas and air mixture by simultaneously changing the sections of the gas and air passages. The mixture remains the same, only a larger or smaller quantity enters the cylinders. The exhaust is opened by a cam. The igniters are also shown.

One of the latest four-cycle engines designed is that of the Vereinigte Maschinenfabrik, Augsburg, und Maschinenbau Gesellschaft, Nürnberg, Actiengesellschaft, which we may refer to as Nürnberg for short. The general design is shown in accompanying views of a 350 horse-power twin gas engine for the Rostock electrical station. (See Plate I.)

The Nürnberg Company has a number of valve gears, the latest being shown on Plate II. On the shaft is a cam *a*, which, through the rod *d e*, actuates the inlet valve through the intermediary of the lever *e f g*. This valve opens inward during the whole of the suction stroke. It is closed by the spring *F'*. In the same valve case is a nearly counterbalanced doubly seated valve, which permits the entrance on the one hand of gas and on the other hand of air in constant proportions. It is operated through the intermediary of the forked lever *m f l* and the inner rod *l k i*. The roller *i* of this rod is in contact with the surface of the lever *c b*, so that this mixture valve is also opened during the entire suction stroke.

The governor acts by displacing the rod *l i*, so that the roller *i* is more or less distant from the fulcrum *c*. In this manner the mixture valve opens more or less according to the position of the governor.

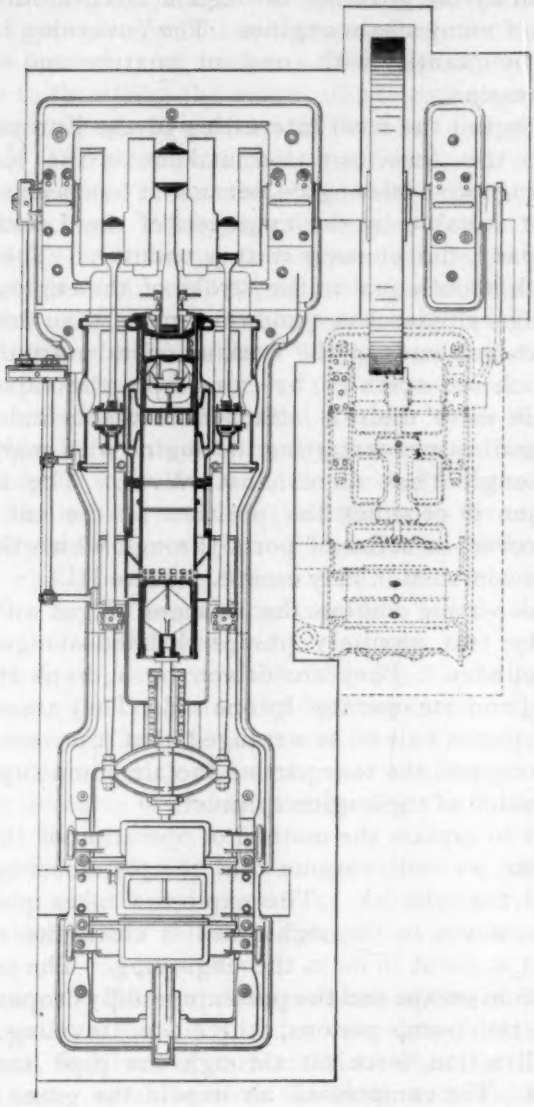
A somewhat different design of the valves of the Nürnberg Company is that adopted for the engine installed at the Rheinische Stahlwerke at Meiderich, which is the largest single-cylinder machine thus far built, and which, according to private advices, is doing particularly effective work. (Plate II.) There are two sets of inlet and exhaust valves, the former lifted by cams. A fifth valve is connected through

short ports with both inlet valves, and it is this valve which is controlled by the governor through a latch motion similar to that of many steam engines. The governing is therefore done by quantity with constant mixture and by variable compression.

In one respect the most interesting of the European gas engines, to the American iron makers, is the Koerting double-acting two-cycle engine, because it has been selected as the most suitable by the engineers of the Lackawanna Steel Company, the pioneers in this country. The piston has a length about equal to the stroke of the engine, while the working cylinder has somewhat more than double its length. At both ends of the working cylinder are the inlet valves, which are operated by cams from the valve shaft. Besides this valve there is attached to the cylinder head only the small valve for starting the engine with compressed air. The engine has no exhaust valves. The working piston, when it occupies the position at the end of the stroke, uncovers a series of ports through which the products of the combustion may escape. (Plate III.)

In the Koerting engine the mixture of gas and air is supplied by two auxiliary pumps, located alongside the working cylinder. They are driven by a crank from the main shaft, and are operated by one rod. They are supplied with plain piston valves, so arranged that the rear part of the gas pump and the rear part of the air pump supply the rear inlet valve of the engine cylinder.

In order to explain the method of operation of the working cylinder, we will assume that the piston occupies the rear end of the cylinder. The explosion takes place and the piston moves to the right until it clears the exhaust ports, as it is about to do in the engraving. The products of combustion escape and the pressure rapidly drops. In the meantime the pump pistons, which are traveling in the opposite direction, force air through the pipe line to the inlet valve. The compressed air expels the gases of combustion, cools the cylinder and forms a separating layer between the gases of combustion and the fresh mixture which now enters the inlet valve. Both the air and the gas pistons



Oechelhaueser 300 horse-power gas motor, driving blowing engine.

are delivering into the rear part of the main cylinder, in the case of the gas, through the ports *b* and *a*. In the meantime a charge has been compressed in the forward end of the working cylinder. The returning main piston compresses the fresh charge in the rear end and the cycle repeats itself.

The gas pump is supplied with two throttle valves, *f f*, so placed that when they open they connect the cylinder port *b* with the gas delivery line *k g*.

To begin with, however, let us assume these valves to be closed.

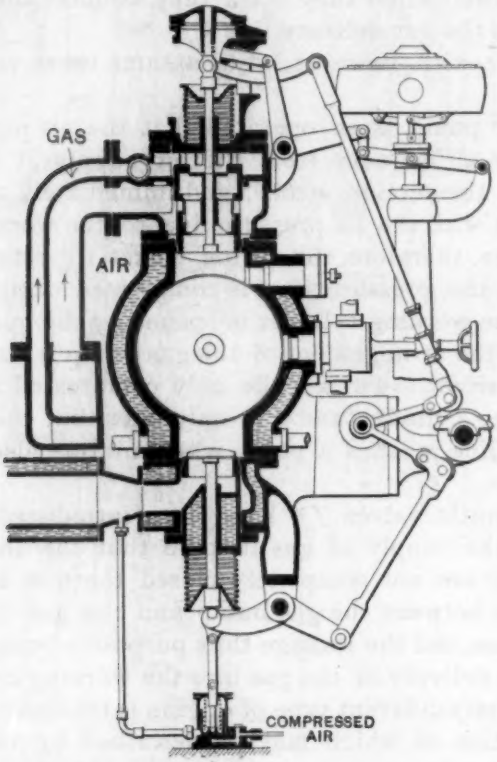
The air pump is so operated that the air piston valve cuts off the air cylinder from the air supply at once after the end of the suction stroke, and immediately afterwards connects it with the air pressure line to the working cylinder. When, therefore, the piston makes its return stroke the air in the pressure line is compressed until the inlet valve of the working cylinder is opened by the gear. In the meantime the arrangement of the gas pump is such that it does not deliver. For a while only compressed air enters the working cylinder, and it is only later that the pressure in the gas line reaches a point, when mixture also is introduced.

The throttle valves *f f* have been introduced in order to lessen the supply of gas in case that the load varies. When they are not completely closed there is a constant connection between the gas pump and the gas line to the main engine, and the leakage thus purposely brought about delays the delivery of the gas into the working cylinder.

An entirely different type of engine is the Oechelhaueser, the operation of which may be described by reference to the accompanying view, which shows the plan of a 500-horse-power motor driving a blowing engine. The cylinder is equipped with two pistons and the engine has no valve gear whatever.

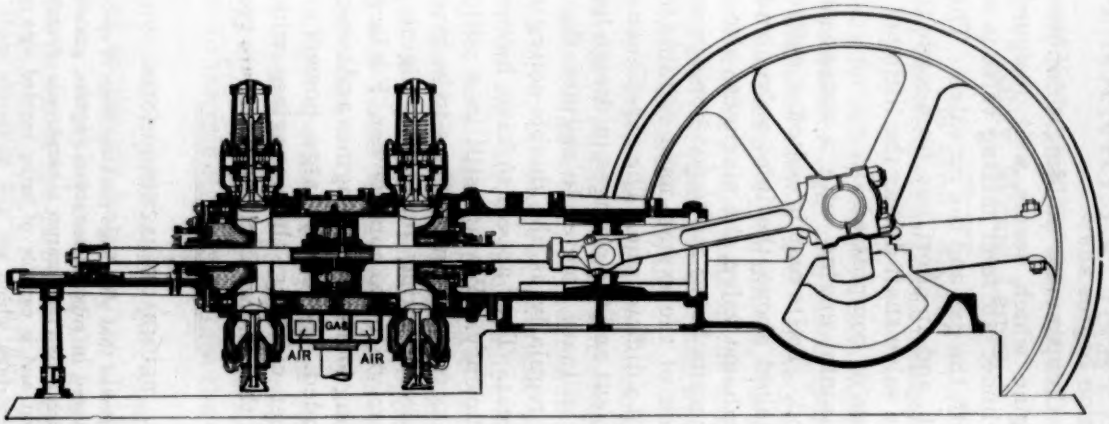
When the two pistons are closest to one another the space between them is filled with a compressed mixture of gas and air. On igniting it the pistons are driven asunder. At first the forward piston uncovers a ring of slits in the cylinder. At this moment the exhaust of the gases of com-

bustion begins. Soon afterward the rear piston opens a second series of slits on the opposite end of the cylinder, through which air compressed to 0·3 to 0·4 atmosphere enters and takes care of the complete expulsion of the residual products of combustion. Then follows a third ring of slits. In the older designs a mixture of air and gas was forced in



Deutz double-acting 4-cycle gas engine. Section through cylinder head.

through these. In the more recent designs it is only gas, so that now the mixture is made in the cylinder proper. Since the exhaust slits open earlier and remain open longer than the gas intake slits there might be some fear that the gas mixture might be blown through. This is improbable, because in normal working a volume of mixture equal to only 70 per cent. of the piston displacement is used. When



Deutz double-acting 4-cycle gas engine. Vertical section.

the return movement of the piston starts, the slits are covered one by one, the mixture is compressed to 8 to 10 atmospheres and the operation begins anew.

The Deutz Company are building a double-acting four-cycle gas engine which seems well designed. At each end of the cylinder an inlet mixing valve is combined on one spindle with the gas and the air valve. The water cooling is thorough, and an effort has been made to relieve the pressure on the valve shaft during the lifting of the exhaust valve by the use of compressed air.

It is a horizontal engine with a water-cooled cylinder open at one end. To its rear is bolted a cylinder head, in which is arranged above the inlet valve, and below the water-cooled exhaust valve, the maximum size of the cylinders for larger units being 250 to 300 horse-power.

The selection of the system most suitable for particular purposes is still a difficult one. The experience accumulated is hardly sufficient and the changes in design have been frequent. The ordinary four-cycle engines do not, on the whole, run as regularly as the double-acting engines and their size is great. They appear to have, however, a higher mechanical efficiency. We are still in a period of active evolution. Thus far preference seems to be given in Europe to the open double-acting four-cycle engine for smaller powers, say from 300 to 400 horse-power. For larger machines the double-acting four-cylinder engines and two-cycle engines are recommended. For very large powers, up to 1,000 horse-power per cylinder, those engines which have no exhaust valve, that is, two-cycle engines, are recommended.

PLUMBAGO PACKING-RINGS.

It has been suggested that plumbago packing-rings of special design could be profitably employed in superheated steam engines, gas engines and other heat motors in which a high temperature is employed. Plumbago or graphite is unaffected by heat and is capable of being molded into permanent form suitable for packing-rings, which are now uniformly made of metal. The chief expected advantage is the mirror-like surface and polish that such rings would impart to a cylinder.—*Iron Age.*

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, April 15, 1903.

Safety Mining Lamps.

By Rufus J. Foster,
Mining Engineer, Vice-President International Correspondence Schools.

The necessity for safety lamps in coal-mining operations is due to the presence of light carbureted hydrogen, CH_4, or marsh gas, in the mine atmosphere. This gas is generally designated as "fire damp" by the miners. It rarely happens that the gas is found in a pure state in the mines. It often contains admixtures of other gases, such as carbonic-acid gas, CO_2, and carbonic-oxide gas, CO.

The term "fire-damp," as used by miners, means also such an admixture of light carbureted hydrogen and air as will form an explosive mixture. Pure marsh gas, or light carbureted hydrogen, is colorless, odorless, and tasteless, and is lighter than air. Its specific gravity is ·559, and it diffuses rapidly in the air and forms a "fire-damp" mixture. It burns with a blue flame, but will not support combustion. Pure marsh gas, or light carbureted hydrogen, is not poisonous, but it will cause suffocation, because it excludes oxygen from the lungs.

Owing to its light specific gravity, marsh gas, or the fire-damp mixture, always lodges against the roof of a mine, or seeks the higher places. It has been a serious and dangerous obstacle to the mining of coal since the very infancy of the industry.

As stated previously, pure marsh gas, when present in small quantities in the air, burns in the flame of a lamp without explosion. As the quantity of the gas is increased, the effect on the flame of the lamp is at once noticeable. As the proportion of gas in the air, is further increased, and approaches the lower explosive limit, the lamp flame enlarges, snaps and crackles. When the proportion of gas to air is 1 to 13, slight explosions occur within the lamp, the

flame of the lamp jumping violently. As the proportion of gas is increased, the violence of the explosion is augmented, until it reaches a maximum when the proportion of gas to air is 1 to 9½ (exactly 1 : 9·38). This is the proportion of gas and air in fire-damp when at its maximum explosive point. From this point, as the quantity of gas is still further increased, the violence of the explosion decreases, until it becomes very feeble when the proportion of gas and air is 1 to 5½, and ceases altogether beyond this point. These limits refer to a fire-damp mixture, consisting of pure marsh gas and air.

For many years the European coal miners regarded explosive gases in mines as supernatural manifestations and

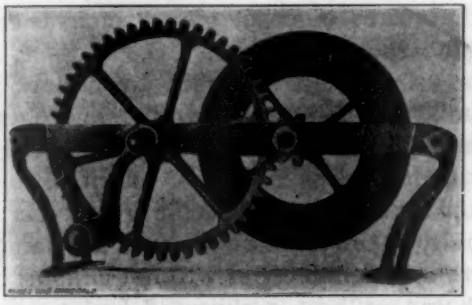


FIG. 1.

as expressions of the displeasure of the goblins at man's presumptuous invasion of their domains. The same idea prevails in China to-day, and it is still a common practice in that country to abandon a coal mine after an explosion, for fear of further angering the dragon spirit.

An examination of the mines before the miners went in to work was practiced in England in a very crude way as early as the middle of the fifteenth century. A dog lowered down the shaft would howl when it entered the fire-damp and it was then withdrawn and the gases cleared away by running a brush tied to a rope up and down the shaft. In Staffordshire a fire boss is still called a doggie.

Candles and various forms of lamps were early used for lighting the mines, and when the working places became

so foul that such lights could no longer be used, skins of putrid fish were hung up and their slight phosphorescence enabled the miner to barely make out the face of the coal. This custom probably suggested the idea of using luminous paints in the mines, tried subsequently, and it developed later into the present very common practice of whitewashing portions of the mine to aid in the illumination.

By the year 1800, steel mills, *Fig. 1*, had come into general use in England for lighting mines, and, though safer than candles, many explosions resulted from their use. The illustrations, *Figs. 1* and *2*, were made from photographs of a steel mill used in English mines as early as 1766.

These mills were operated by boys, usually the sons of the miners, each miner taking his boy into the mine and requiring him to almost continually turn the wheel with one hand while he held a piece of flint against the wheel with the other, as shown in *Fig. 2*. The resulting shower of sparks, while a beautiful pyrotechnic display on a small scale, gave but little real light.

During the early years of the nineteenth century the ever-recurring disastrous explosions throughout Great Britain made a great impression upon the Rev. John Hodgson, a clergyman of the North of England. At that time the newspapers did not publish accounts of explosions in the mines, and they were given as little publicity as possible, so as to avoid giving offense to the colliery owners. The Rev. Mr. Hodgson, however, in the face of public opinion, gave an account of a serious explosion which occurred at the Felling Colliery, May 25, 1812, by which ninety-two men and boys were killed, and after this in every possible way he directed public attention to the subject of mine accidents.

These public notices attracted the attention of Mr. J. J. Wilkinson, a Barrister-at-Law of London, through whose efforts the "Society for the Prevention of Colliery Accidents" was formed October 1, 1813. Soon after the formation of this society, the assistance of Sir Humphry Davy was solicited to solve the problem; but the letter inviting his assistance miscarried, and it was not until three years later

that the matter was brought to his attention. Sir Humphry at once reviewed all that had been written on the subject, and then visited the mines of the North of England, where he studied the practical considerations connected with the use of lamps about the mine and consulted with mine operators. Mr. Hodgson made known to him a theory that the fire-damp came from the coal itself and not from the decomposition of the coal or the water or of the pyrites, as was commonly supposed. Sir Humphry Davy immediately went into the dining-room of Mr. John Buddle, with whom he was staying, and broke some pieces of coal under water, when gases were seen to bubble up through the water, thus showing that Mr. Hodgson's ideas were probably correct. Sir Humphry next visited Dr. Clanny and inspected a lamp he had made; then returned home and immediately began his experiments, which from the first were encouraging. He soon discovered the action of wire gauze upon a flame, and early in January, 1816, only about five months after he began his investigations, sent three "Davy's" to Newcastle, where they were first tested at the surface and then underground, and during the same year they came into general use throughout the North of England. Although, of course, modified in its details, the present Davy lamp is entirely similar to these first sent out by Sir Humphry Davy.

Although Sir Humphry Davy invented the first practical safety lamp, the honor of first suggesting a method for insulating mine lights belongs to Dr. Clanny, a physician of Sundaman, England. Late in the year 1811, or early in 1812, he constructed a small lamp of strong glass, the bottom of which was closed with the exception of a small opening to admit air to the enclosed candle, the necessary amount of air for combustion being furnished by bellows. He afterwards, also unsuccessfully, tried a lamp insulated by means of valves, but at last he succeeded in making a perfectly insulated lamp by passing the air from the bellows through a stratum of water below the flame, while the products of combustion escaped through a stratum of water above. Although none of these lamps came into practical use, Dr.

FIG. 3.

FIG. 2.

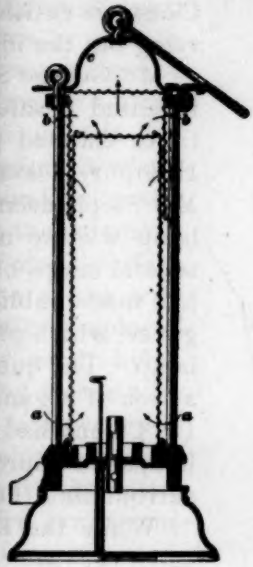


FIG. 4.

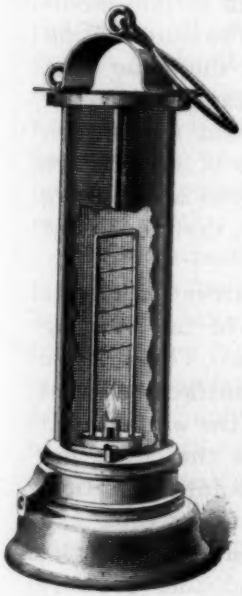


FIG. 5.

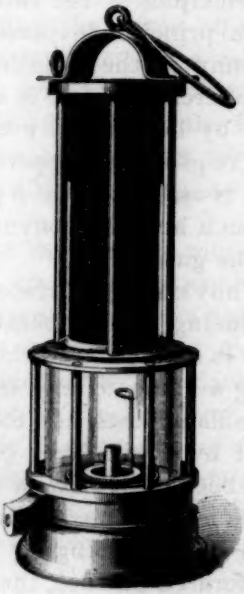


FIG. 6.

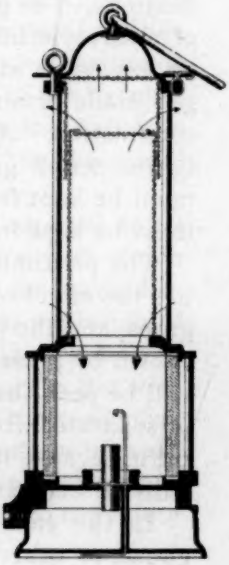


FIG. 7.

Clanny is entitled to the credit for conceiving and first carrying out the idea of constructing an insulated lamp.

Mr. George Stephenson, from the North of England, also invented a safety lamp, and his friends have at various times claimed priority for his invention over that of Sir Humphry Davy. The records seem to show that while Mr. Stephenson undoubtedly invented a safety lamp, this lamp was no more of a practical success than were the several lamps of Dr. Clanny, until after Sir Humphry Davy had made public his discovery of the cooling action of wire gauze, which principle Mr. Stephenson then applied to his lamp. The question of priority of discovery of the cooling action of a gauze or thin plate is still an open one. After Dr. Clanny had tried both the Davy and the Stephenson lamps, he improved the illuminating power of the Davy by surrounding the light with a glass cylinder.

While the Davy and Clanny lamps of to-day are practically the same as those first produced by Sir Humphry Davy and Dr. Clanny, all other types are combinations and adaptations of the principles of the two, with certain modifications. The general principle involved in the construction of a safety mining lamp is the isolation of the flame from an explosive atmosphere. A flame is a stream of vapor or gas made luminous by heat, usually the heat of its own combustion. As it requires a temperature of 1,220° F. to ignite marsh gas, it is essential that a gaseous atmosphere must be kept from such heat, or, conversely, that such heat must be kept from the gas.

The proximity of any cooling surface whatever to a flame has the effect of reducing the temperature of the burning gases, and the flame is extinguished thereby. This may be shown by presenting a flame to any cold surface, when it will be seen that the flame does not touch the surface. It is separated from it by a thin layer of gas that does not burn, because it has been cooled below the point of ignition. This will continue as long as the surface remains cool.

In the case of a flame impinging against a cool wire gauze, or other perforated surface, the conditions are very favorable for the cooling of the gases of the flame below

the point of ignition. As they pass through the small openings, the gases are divided into minute streams or jets by the meshes of the gauze and cooled instantly, being thereby extinguished. It was this fact that Sir Humphry Davy discovered and which led him to the conclusion that if a lamp flame could be surrounded by an iron gauze it would be prevented from spreading to the surrounding gases. The discovery of this principle at once led to the surrounding of the flame of an ordinary lamp by a metal surface having numerous apertures. Davy made use of the wire gauze for this purpose, while George Stephenson employed a metallic surface punched with numerous small holes. The principle of the isolation of the flame by means of a cold metallic surface, while the light of the lamp was permitted to pass through small apertures, is the same in each of these, but the gauze employed by Davy gave the better light. His experiments showed that a fine wire gauze, composed of wire $\frac{1}{40}$ to $\frac{1}{60}$ inch in diameter, having 784 openings to the square inch, formed by crossing twenty-eight parallel wires, would not permit the flame to pass outside the lamp. By enclosing the flame of an oil lamp within such a gauze, it is surrounded by a safety shield. When the lamp is placed in an explosive mixture, the gas inside the gauze is ignited and burns, but the flame of the burning gases inside the lamp cannot pass through the gauze to ignite the gases outside the lamp, as long as the gauze remains cool.

In the extraction of the coal the miner is exposed to all the dangers incident to a gaseous atmosphere, with which he is continually surrounded. These dangers are twofold in their nature: (*a*) The danger arising from an explosion of mine gas due to its ignition by the flame of a naked lamp or of a blown-out shot, or the sparking of an electric wire or other cause; (*b*) the danger arising from the poisonous effects of many of these gases, or from suffocation because of their inability to support life. It is the first of these two classes of dangers that we consider in reference to the safety lamp.

Safety lamps may be divided into two general classes, according to the uses for which they are to be employed:

(1) Lamps for general use at the working face.

(2) Lamps for testing for gas.

There are some lamps that are designed for general use only, others are designed for the purpose of testing for gas only, while still others are constructed so that they may be employed for both purposes. A lamp, however, that is very sensitive to the presence of mine gas, and thus possesses one of the most important requirements for testing for gas, does not make a good lamp for general use at the face, for the reason that it will require too much watching on the part of the miner in order to avoid the possibility of the flaming of the lamp. On the other hand, a lamp that possesses all the requisites of a good lamp for general use is not adapted to testing for gas.

The following may be stated as the requisites for a good lamp for general use:

(*a*) Maximum illuminating power.

(*b*) Safety in strong currents.

(*c*) Simplicity of construction.

(*d*) Security of fastening or lock.

(*e*) Minimum liability to flaming and internal explosion.

The requirements of a good lamp for testing for mine gas are:

(*a*) Sensitiveness to small percentages of gas.

(*b*) A small, uniform, non-luminous flame.

(*c*) Free entry of air into the lamp below the flame.

(*d*) Drawing gas into the lamp from a thin layer at the roof.

These several requirements are attained by several different forms or types of construction. The illuminating power of the lamp is increased by as free an entry of air into the lamp as possible. The entry of the air should preferably be at a point below the flame; but when the air enters the lamp above the flame a deflector is often used to separate the ascending and descending air-currents, so as to prevent the smoking of the lamp. The illuminating power is also increased by increasing the draft of the lamp, which is accomplished in the Mueseler lamp by a wrought-iron or copper conical chimney placed within the lamp gauze imme

diately above the flame. Safety in strong currents is secured by bonnets placed outside of the gauze, or by simple gauze chimneys, as in the Marsaut lamp. Simplicity of construction is important for purposes of thorough and rapid cleaning. There are several forms of lock in use, most common among which are the lead plug lock, and the ordinary turnbolt requiring a simple split key. More recently magnet locks have been introduced, as in the Wolf lamp, that can only be opened by means of a strong magnet. These, perhaps, furnish the greatest security.

The liability to flaming is largely reduced by a good circulation within the lamp. Security against internal explosions is obtained by means of multiple gauze chimneys and also by metal bonnets. The sensitiveness of the lamp, and its power to detect small percentages of gas in the mine air, which makes it valuable for testing, is secured largely by the free entry of air into the lamp at a point below the flame. This is best attained in the simple Davy lamp, which has always been a favorite with fire bosses.*

The Davy lamp is shown in *Figs. 3* and *4*. The style shown is the lamp used by working miners. There are several different forms of the Davy lamp, but they differ only in size and in the shape of the oil cup. In *Fig. 4* the arrows marked *a* show the ingress of the air to support combustion, and the egress of the products of combustion is shown by the arrows at the top. There is a double gauze at the top formed by a gauze cap over the main gauze; this is shown by the letter *b*. The gauzes are held in place by the hood *c*, which is hinged and clamped in place by the eyebolt shown just above *b*. The principal use of the gauze cap is to prevent the liability of the gauze being burned through at the top. As shown, the air enters the lamp freely through the gauze, all around the flame, and passes out through the upper part of the cylinder and the gauze cap.

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* To illustrate his paper, Mr. Foster had on exhibition a collection of forty-two different safety lamps, part of the collection of the School of Coal Mining of the International Correspondence Schools. As it is impracticable to illustrate all of them in the JOURNAL, only such as are distinctive in type are shown in the illustrations.

This free passage of the air into the lamp at a point below the flame insures a good flame cap for testing purposes. The lamp, however, flames easily, and when unbonneted is not safe in a current whose velocity is greater than 6 feet per second, as the flame in the lamp is liable to be blown through the gauze. When used by a fire boss for testing purposes, the flame is turned low by use of the hooked wire picker shown in the sectional view. The lamp is then carefully lifted toward the roof of the mine. If there is gas present in small quantity a cap or halo shows on top of the flame. If in larger quantities, the gas burns with a blue flame inside of the gauze. When the presence of gas is thus shown, the fire boss carefully and slowly lowers the lamp, until it is either below the stratum of gas and retreats with the lamp held near the floor, or he puts it under his coat and extinguishes the flame inside the gauze by smothering it, and he retreats in the dark.

The most recent improvement in the Davy lamp for testing purposes is the Beard-Mackie safety-lamp attachment. It is the joint invention of Prof. J. T. Beard, Principal of the School of Coal Mining of the International Correspondence Schools, and Matthew D. Mackie, an experienced fire boss in the employ of the Delaware, Lackawanna and Western Company. It is a sight detector of simple design and can be used in almost any testing lamp. It consists of an iron or brass rod so bent that it forms two parallel legs of any required length, and from $\frac{3}{4}$ inch to 1 inch apart. The two ends of the rod are soldered to a brass ring which fits down over the burner of the lamp, and which is held in place by any kind of a set-screw or clamp, and the two legs extend perpendicularly into the lamp to the desired height. Strands of fine platinum wire, at regular distances, are stretched horizontally from one leg to the other. This makes a miniature ladder with brass or iron sides and platinum-wire rounds. The lower strand is arranged at such a height as to be just at the point of incandescence when the lamp is in pure air. The successive strands above this are arranged at such heights as will indicate the percentage of gas, if that is desired, or less accurately for

practical testing purposes, to show danger points. The practical value of the device lies in the latter feature, and the fact that it readily shows the relative explosiveness of the mine air, and the fluctuation in the amount of gas present.

This device is shown in *Fig. 5*.

In testing for gas, a reduced flame in the lamp is used, and the heights of the wires must in such cases be adjusted accordingly, and they will be equally as effective as when a normal flame is used.

On account of the sensitiveness of the platinum wire, due to its absorption of the gas, it becomes incandescent at a much greater height than is reached by the flame. In the use of a flame ¾ of an inch in height, the strands will glow brightly to a height of 1¼ inches above the tip of the luminous flame when 2 per cent. of gas is present.

This appliance has been unanimously endorsed by the Association of Fire Bosses of the D., L. & W. mines. I recently saw a demonstration of its action when used in a Davy lamp in a gaseous atmosphere, and I was particularly attracted by the positive, sharp manner in which the incandescing of the successive wires indicated the increasing percentages of gas, and also with the fact that the lower wires were brightly incandesced by so small a percentage of gas as would hardly show a perceptible cap on the flame.

There are as many, if not more, forms of the Clanny lamp than of the Davy. All of them are, as in the case of the Davy, simple modifications of the original lamp. The characteristic feature of the Clanny lamp consists in the substitution of a strong glass cylinder for the lower part of the gauze cylinder of the Davy lamp. In other respects it is the same as the Davy lamp. The entry of the air in the Clanny lamp, however, takes place above the glass cylinder, *Figs. 6* and *7*, the entering air descending inside of the lamp to the flame. This gives rise to conflicting descending and ascending air-currents within the lamp, which often produce a smoky flame. This feature of the Clanny lamp impairs its illuminating power, as the glass cylinder becomes smoked and the flame itself is not as bright, owing

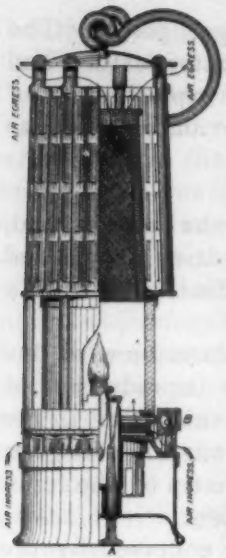


FIG. 8.

FIG. 9.

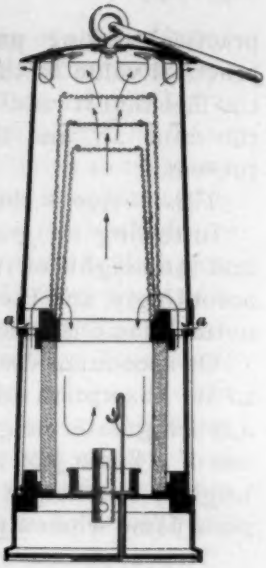


FIG. 10.

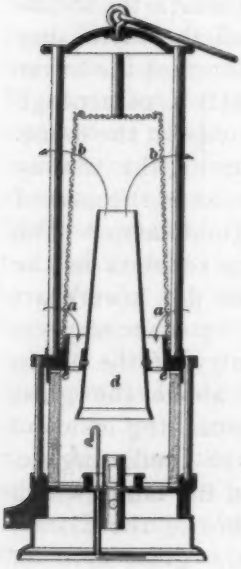


FIG. 11.

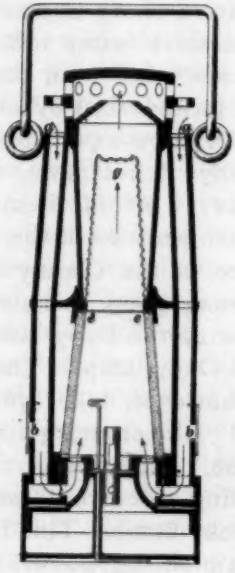


FIG. 12.

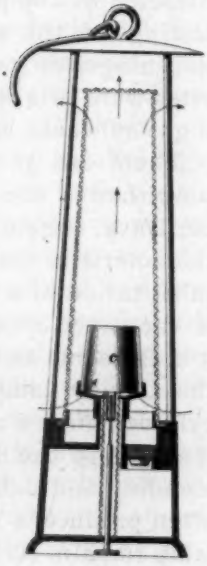


FIG. 13.

to insufficient draft. The lamp does not present the conditions favorable for testing for gas, the lamp flaming readily in a body of fire-damp, and the flame not being sensitive to small percentages of gas. This lamp is also made in brass and aluminum, and with various forms of lock fastenings and oil vessels.

The unbonneted Clanny lamp is not safe in a current of air having a greater velocity than 8 feet per second. One improvement which tends in a slight degree to obviate this fault is a small iron or copper shield about 1 inch in width surrounding the lower part of the gauze immediately above the glass cylinder. While this is a slight improvement, it is not as effective as the bonnet, which completely covers the gauze cylinder, except that means are left for the egress of the products of combustion near or at the top.

The Wolf lamp is one which has met with practically unanimous approval from mine managers both in this country and in Europe. It is the invention of Mr. C. Wolf, of the firm of Friemann & Wolf, of Zwickau, in Saxony. The lamp shown in *Fig. 8* is the latest type of the Wolf lamp. It was evolved from the Clanny lamp.

The chief characteristics of this lamp are: (1) The adaptation of the oil cylinder for burning naphtha, thereby greatly increasing the illuminating power and the sensitiveness of the flame; (2) the introduction of an ingenious igniting arrangement, which permits the miner to relight the lamp without danger in case the flame is either accidentally extinguished or has been extinguished by gas burning inside the gauze; (3) a magnet lock or fastening which prevents any tampering with the lamp by the miner. The lock can only be opened by the use of a very strong and heavy magnet at the surface or lamp station.

At first the idea of the use of so volatile an illuminant as naphtha prejudiced many mining men against this lamp; but the method of using the naphtha, and the use of an automatic lamp filler overcomes all the objections. The naphtha in the oil chamber is held in an absorbent material, and the flame is fed from the volatile gas arising therefrom. The flame is a particularly bright one, and has about double the

candle-power of the best safety lamps of other types. The cost of the naphtha is about one-quarter that of the oil used in other lamps. The Wolf lamp is essentially a working lamp, and is not intended for testing purposes. It will show the presence of gas in the air when the percentage is as low as 1 per cent., but it will invariably go out before the mixture of gas and air reaches the explosive point.

The manner in which the lamp takes its air is shown on *Fig. 8.* It enters in a tortuous way through port-holes below the flame, passing through a gauze ring before it enters the lamp, and the products of combustion find egress from the top of the double conical gauze chimneys, as shown by the arrows. The gauze chimneys are protected by a bonnet, which completely surrounds and extends above them. This bonnet is fluted and contains a number of port-holes, which are so arranged that an air current blowing against the lamp cannot find direct ingress. The thumb-screw, by means of which the igniter is operated, is shown at *A*, and the magnetic lock at *B*. This lamp has been proven capable of withstanding an air current with a velocity of more than 59 feet per second. Its value as a safe lamp is attested by mine officials and mine inspectors, and it is so highly esteemed that the Bituminous Mine Law of Pennsylvania, which formerly strictly prohibited the taking of volatile oil into a bituminous mine in Pennsylvania, was, at the request of mine officials and mine inspectors, amended in 1901 to read: "No volatile oil, *except when used in approved safety lamps*, shall be taken into any mine," etc.

These lamps are made of various metals, including aluminum alloy, the latter material making an exceedingly light-weight lamp.

Messrs. Friemann & Wolf have just placed on the European market a new lamp known as the Wolf-Stuchlik lamp. This lamp retains the general form of the Wolf lamp shown, but the oil chamber, instead of being constructed for the use of naphtha, is constructed as an acetylene lamp. This lamp will give a light equivalent to 7 candle-power, as against $\frac{6}{10}$ candle-power of the best oil-burning safety lamps, and the 1 candle-power of the Wolf naphtha lamp. There

is a horizontal reflector affixed to this lamp, which, when so desired, reflects the light against the roof; the upper frame of the lamp and the handle by which it is carried being so arranged as not to interfere with the rays of light. This lamp has not as yet reached this country, and I am merely giving a brief statement of a written description of it which I have seen. That it gives increased light without increased danger, and that by its use the mine-roof can be inspected, are features of great value.

The Marsaut lamp is similar to the bonneted Clanny lamp in every respect, but is supplied with three gauze chimneys as shown in *Figs. 9* and *10*. It is a peculiarly strong lamp in this respect, as the security against explosions of gas within the lamp is thereby increased. This lamp is often extinguished in an explosive mixture by the force of the explosion within itself. It gives a good light and is a good lamp for the working miner. The Marsaut lamp has been improved by the addition of a deflector known as Howat's deflector. This consists of an annular ring placed about 1 inch above the top of the glass cylinder, and so as to fill the annular space between the bonnet and the gauze. Resting on top of the cylinder, and extending almost up to this annular ring, is a metal diaphragm which serves to deflect the entering air down upon the flame. This greatly increases the illuminating power of the lamp.

In the Mueseler lamp, *Fig. 11*, the attempt was first made to increase the draft, and thereby improve the illuminating power and prevent smoking. The lamp is provided with a central conical tube or chimney *d*, of sheet iron, held in position by a horizontal perforated diaphragm of sheet iron *e*, *e*, at the junction of the gauze and glass cylinders. Air enters the lamp through the gauze *a*, *a*, and, passing through the perforations of the diaphragm *e*, *e*, is drawn down under the expanded mouth of the central chimney in close proximity to the flame, and passes out the chimney and through the gauze *b*, *b*. The draft of the chimney materially increases the illuminating power of the lamp, while the central tube adds very largely also to the security of the lamp against currents and inner explosions, the latter seldom being com-

municated outside of the lamp. It is not a lamp adapted to the detection of gas, but it is reported to have safely withstood a current of 100 feet per second. It does not flame as quickly as the Clanny lamp. This lamp is made with or without a bonnet.

The Ashworth lamp has the flame surrounded by a conical glass chimney, which at the top fits into a brass cap surmounted by a single gauze about 1½ inches in height, also conical in shape. This gauze is surrounded by a brass cylinder which is conical at the top and open. The entire upper part is encased by a brass shield perforated on the sides and top. The air and mine gases enter through these perforations, pass down through the standards connecting the brass shield and the lower part of the lamp, then through a narrow gauze about ½ inch high, placed directly beneath the glass chimney, and into the flame of the lamp. The hollow standards also have openings at the bottom, which are ordinarily kept closed by a slide, but the slides may be raised and the air thus taken from a point near the base of the lamp.

The Gray lamp is a Clanny lamp with the wire gauze of the upper half of a Clanny replaced by a solid metal chimney, which opens into a low cylindrical space surrounded by a wire gauze. The top of the lamp is perforated and protected by a horizontal wire gauze. All of the air enters from the extreme topmost point of the lamp, and is then led through four hollow standards connecting this top chamber with the base of the lamp into the combustion chamber below the flame.

The Ashworth-Hepplewhite-Gray lamp, shown in *Fig. 12*, is an improved combination of the Ashworth and Gray lamps. It is one of the best and most convenient of the lamps for testing for gas. When the lamp is being used for testing, the air enters the tops of the four standards, *a*, *a*, and passing down through the standards, enters the lamp below the flame, thereby producing the best conditions for yielding a good gas cap. The glass chimney, *e*, *e*, tapers toward the top, and the same conical shape is also given to the gauze chimney *g*, which is bonneted as shown. The

conical shape of the glass assists the upward diffusion of the light, and makes the inspection of the roof easier, while the same shape in the gauze chimney renders the lamp more safe and secure against an inner explosion of gas being communicated outside of the lamp. The air being drawn into the lamp through the top of the standards makes it possible with this lamp to detect a thin stratum of gas near the roof. When not in use for testing, the air may be admitted at the bottom of the standards, at *b*, *b*, by moving a little shutter that closes them.

The wick of this lamp, when at a normal height, furnishes a flame of great illuminating power. When lowered by a fine screw adjustment, the flame becomes blue and non-luminous, and does not interfere, therefore, with the easy observation of a pale cap.

The Pieler lamp, shown in *Fig. 13*, has a gauze similar to a Davy lamp, but burns alcohol instead of oil. In its form, the gauze is bonneted by a sheet-iron bonnet, the gas caps being observed through a glass window. This window is very apt to become dimmed with smoke and moisture, thus impairing the observance of the caps. A shield *c* surrounds the flame, which is adjusted so that its tip does not extend above the top of the shield.

This lamp was designed by the inventor to yield a standard flame which would always present a certain height and volume, and yield flame caps of a uniform height for given percentages of gas. The following table was prepared by him to show the percentage of gas corresponding to different heights of flame caps, measured from the top of the shield *c*:

¼ per cent. of gas yields a cap 1·25 inches high.
½ per cent. of gas yields a cap 2·00 inches high.
1 per cent. of gas yields a cap 3·50 inches high.
1½ per cent. of gas yields a cap 4·75 inches high.
1¾ per cent. of gas cap reaches the top of the lamp, and beyond this percentage of gas the lamp fills with flame.

The lamp flames easily in a mixture containing more than 1¾ per cent. of gas, and is, therefore, dangerous, re-

quiring great care and caution in its use. Any variation in the strength of the alcohol varies the height of the flame, which is, therefore, not strictly a standard flame.

The Dick lamp is another of the various forms of the Clanny lamp which have been introduced. The features of this lamp are the insertion of a rim of brass or zinc in the upper portion of the steel bonnet, for the purpose, it is claimed, of reducing the conductive power of the bonnet and cooling the lamp. Another essential feature of this lamp consists in the tangential position of the port-holes by which air enters the lamp through the bonnet. There are several rows of these port-holes extending around the bonnet and also the brass ring mentioned above. There is also a circular air box immediately above the glass cylinder, which is constructed to admit the air into the lamp through a separate gauze. This air supplies the flame of the lamp, while the air entering through the tangential port-holes in the bonnet serves the purpose of cooling the gauze chimney. It has never come into general use. The Derbyshire Clanny lamp differs from the ordinary bonneted Clanny, only in having a small inner bonnet at the top of the lamp for the more thorough protection of the openings at the top of the outer bonnet. The Garforth lamp is another type of the bonneted Clanny, from which it differs in no essential particular.

The Mauchline lamp is a simple unbonneted Clanny, in which the glass cylinder is replaced by a strong convex lens in one side of the lamp, while a reflector is placed in the opposite side. Between these, upon either side of the lamp, are small circular openings for the entrance of air, protected by gauze. It was designed for use in making mine surveys, but has only been used to a limited extent.

There are numerous modifications of the Clanny and Davy lamps, designed for the use of fire-bosses, besides those already mentioned and described. As they have not won even partial approval from mine officials, the writer does not think it well to enter into descriptions of them. In the collection of lamps they are simply curiosities.

The Marshall lamp has a conical bonnet, inside of which

is a single gauze, this gauze being surrounded at the bottom by a second gauze and being connected at the bottom and on the inside to a metal deflector. The glass part of the lamp is entirely similar to the Clanny. Surrounding the glass chimney are five upright standards, one of which is movable up and down; by moving it downward, the upper part of the lamp can be locked to the oil chamber, and then by means of a hasp and staple the parts of the lamp are still further locked.

The Clifford lamp has a double bonnet, which is perforated to admit air. The lower part of the lamp very closely resembles the ordinary Clanny; but above the flame, and in place of the inclined metal chimney of the Mueseler lamp, is a bell-shaped glass chimney, like the lower part of an argand chimney. This fits into a metal tube, about which, at its connection with the argand chimney, is a double gauze, which completely insulates the flame chamber. This metal chimney opens at the top into a cylindrical chamber, which has a small opening at its top and across which is a gauze.

The Cosset lamp is a form of the Mueseler lamp, manufactured in France. In the ring, in which the lower ends of the standards rest, is a series of depressions or notches. A pin projects from the upper rim of the oil cup, and this pin is forced upward by a spring, but it can be withdrawn by turning a screw at the bottom of the oil vessel. This same screw also lowers the wick, so that when the pin is being withdrawn the wick is also being screwed down so low that the light will be extinguished. Desiring to use the lamp, the wick and pin are raised by turning the screw at the bottom of the oil vessel. The wick is lighted and the oil cup is then screwed into the top part of the lamp. It cannot be unscrewed as long as it is burning, because the projecting pin in the oil vessel catches in the depressions previously mentioned, which act like a ratchet, and to withdraw this pin also withdraws the wick and extinguishes the light.

The New Type Cosset lamp is a two-gauze Marsaut lamp of French manufacture. The upper rim of the oil

vessel has teeth which form a rack. The glass cylinder of the lamp is surrounded by six standards. One of these standards is hollow and can be detached from the lamp. At either end of the detachable standard are projecting pins forced outward by springs within. One of these projections, when the standard is upon the lamp, passes down through the lower ring surrounding the glass and rests upon the rim of the oil cup. The upper projection contains a small hole, and this hole extends above the upper rim, which holds the standards. When the lamp is to be used the movable standard is placed in position, the wick ignited, and the oil cup screwed into the body of the lamp. A lead plug is then placed through the hole in the upper projection of the movable standard. In this condition the lamp cannot be opened, because the lead plug in the upper end prevents that projection from being depressed, so the standard can be entirely removed, and until that is done the lower projection catches upon the teeth of the rack on the oil vessel and prevents the latter from being turned.

The Cambessedes lamp is also a French lamp, having a broad circular base, hollow standards like the Ashworth-Hepplewhite lamp, and an argand burner like the Pieler. An extra oil reservoir extends half way around the glass cylinder. This oil vessel is made of a light-colored metal, and the side turned toward the flame is polished so as to act as a reflector. A circular disk of gauze fits over the top of the hollow standards, and is held in place by a circular plate, through the center of which a conical chimney is passed to within an inch or so of the wick. This chimney is surrounded by the usual cylinder of gauze, which extends to the top of the lamp. The air is always admitted through the circular disk of gauze at the top of the standards, passing down through them and up into the flame. The wick is raised and lowered by turning a thumb-screw at the side of the oil vessel. A wire passes through the bottom of the oil vessel to the wick, to remove from the latter all charred particles that adhere to it. This wire is held in its highest position by means of a hooked piece of metal soldered to the bottom of the oil vessel, under which

the bent end of the wire is slipped. This prevents it from sliding down and becoming bent when the lamp is set down, a difficulty experienced with the wire "pickers" for raising and lowering the wicks, which are common in so many kinds of lamps.

All of the lamps described, except the Ashworth-Hepplewhite-Gray, the Pieler, and the Wolf lamps, are constructed to burn either vegetable or seal oils. Light mineral oils are burned in the three exceptions.

According to the English Mine Commission, the safest oils to use are vegetable oils, such as rape, made from rape seed, and colza, made from cabbage seed, and seal oil. None of these are explosive. Petroleum used alone is liable to explode, and should be avoided.

In point of brilliancy, the flame of a lamp burning seal oil is superior to one burning either rape or colza oil, and the wick is less liable to become charred.

By addition of one part of petroleum to two parts of rape-seed oil the light is increased.

Many of the oils in common use in safety lamps have a tendency to incrust the wick and thereby lower the flame. Petroleum or benzine added to the oil reduces this tendency and yields a better flame for testing purposes. Alcohol yields a hotter and less luminous flame and a much higher cap. In some cases, a hydrogen flame has been used for testing purposes. The hydrogen is compressed into a small steel cylinder attached to the lamp, and is burned in the lamp at the mouth of a small tube. This apparatus gives a standard flame for testing, but it cannot always be conveniently obtained.

PUPIN AND JENTSCH ON TRANSOCEANIC TELEPHONY.

Dr. Jentsch, of the German telegraph service, recently criticised Prof. Michael Pupin's system of long-distance telephony. His objections were leveled, not at the electrical features of the system, but simply at certain mechanical difficulties that might be encountered. In his opinion, external pressure of the water would increase with the depth to which a submarine cable was laid. At a depth of 2 or 3 miles it would not be impossible that a pressure of 3,000 pounds to the square inch would be found. From this Dr. Jentsch concluded that the inductance coils of Pupin, unless constructed

with extraordinary strength, would be crushed in. Dr. Jentsch, however, as well as Professor Pupin himself, agrees that the difficulty is by no means insurmountable.

It has also been said that transatlantic telephony will not pay. Professor Pupin is himself of that opinion, not because of any inherent fault in his system, but because of the customs of the business world. A transatlantic telephone system would be used chiefly during the business day of six or seven hours. Since the day begins in London and Paris five hours earlier than it does in New York, it follows that only during a period of one or two hours would the line be in use. Professor Pupin's system, however, is equally adapted to the improvement of the submarine telegraph cable, so that its practical utility is by no means as curtailed as it might seem.—*Scientific American.*

DAMAGES CAUSED BY STRAWBOARD WASTE TO NATURAL WATER RESOURCES.

A serious damage to water resources, as well as to all vested interests along water courses in the United States, arises from the deposit of industrial wastes in streams that drain the manufacturing centers of the country. Among the wastes so deposited, that which is derived from strawboard mills is probably the most troublesome. In the region north of Ohio River, where there are a large number of manufacturing plants of this character, the effects of strawboard waste have attracted great attention and have resulted in many suits at law for damages of one nature or another.

Strawboard waste is composed of small particles of straw, which, in the violent process generally used to reduce the stalks to their component cellulose fibers, are broken and ground to such a state of fineness that they readily pass out of the washing machine along with the waste water. This material is composed largely of the hard, glazed covering commonly observed on all straw stalks, and, as it contains a high proportion of silica, it is extremely difficult to treat or to utilize in a satisfactory manner. In addition to the straw particles there are varying quantities of waste lime and a fairly high proportion of extractive matter.

This waste mingles with other organic matter in a stream, and as a result there is produced a foul, reeking mass, which absolutely destroys fish life, ruins for agricultural purposes land which it overflows, unfits water for domestic supply, and is often highly damaging to residential property.

The United States Geological Survey has succeeded in enlisting the co-operation of several eminent authorities in the work of discovering the most practicable and economical means of purifying strawboard waste. Into this work the officials of the American Strawboard Company have entered with gratifying enthusiasm, and there is assurance that within a short time methods of disposal will be completed and adopted.

Experiments on the subject are being conducted at the Massachusetts Institute of Technology, Boston, Mass., under the direction of Prof. Wm. T. Sedgwick; at Earlham College, Richmond, Ind., under the direction of Prof. Robt. L. Sackett; and at Purdue University, Lafayette, Ind., by President W. E. Stone and Prof. Severance Burrage. These experiments are under the general supervision of Mr. M. O. Leighton, hydrographer, United States Geological Survey.

ELECTRICAL SECTION.

Stated Meeting, March 12, 1903.

Defective Machine Insulation.

By C. E. Farrington.

The best excuse for a forty-five-minute talk on the defective insulation which is found in modern dynamo and motor construction is the statement that it is the greatest obstacle to electrical development at the present time.

It is a fact beyond controversy that the electric motor is not being used as much as it would be if it were a more perfect machine.

A veteran railway superintendent, whose title was once "barn boss," recently told me how much he wished that he could have as little sickness in his motors as he used to have among the horses.

My connection with the manufacture of electrical insulation was brought about through the request of a large electrical manufacturing company for a substitute for shellac as an insulating varnish. This was some ten or twelve years ago, when all that any paint and varnish chemist knew about insulation was what he might derive from the examination of a dictionary; so we asked our electrical friends for full details of the work an insulating varnish had to do.

The answer, signed by one of the best known of the large construction concerns of a dozen years ago, is in my possession to-day, and reads: "An insulating varnish must contain as little water as possible and dry quickly. We cannot give you further details; but if you will make the varnish as above stated, we will make the tests to see whether it has any insulating properties."

If such an answer had been rendered on any other point concerning mechanical or electrical engineering, it would have been considered a glaring admission of ignorance, and no large electric company would have tolerated such ignorance after it had once exposed itself.

But it is a fact that electrical engineers have neglected to use the methods of applied chemistry in this most important item of their work. They have cheerfully gone on and on, jauntily ignoring well-known chemical law and trusting to the cleverness of their sales departments to shift to buyers the responsibility for losses and annoyances which might be wholly avoided were conscientious study made of the problem.

By our inquiry we finally ascertained that shellac varnish (gum 'lac dissolved in alcohol) gave the best results of anything which they had then used, but that electricians were quite well aware that it was defective. As no further information was forthcoming, we proceeded to make a very rapid drying copal varnish, which was duly submitted to our electrical friends, and after a few days' test it was adopted by them and its use commenced in considerable quantity. It was the first insulating varnish ever made.

As an illustration of what we have learned since then, I will say that no competent engineer will now concede that a given compound has any insulation value whatever until his tests have been those of actual service under widely different conditions and unless the time test is at least a year.

We submitted samples of our insulating varnish to several other electrical concerns, and invariably received flattering testimonials as to the wonderful insulating properties which it possessed. We gave it the name "Insullac," and I think during the next six months we unintentionally crippled as much machinery as we insulated. I think the record which we made at that time has been equalled once or twice since by some of our enterprising competitors. But in justice to them, I must say that they were guided by just the same sort of advice as we had.

The experience of that six months produced a profound impression. Savage complaints convinced us that the testimonials of our electrical friends were better testimony of their ignorance of the chemistry of insulation than of the quality of the material whose praises they sang. Our surprise and regret were superseded by an ambition to atone for our error, and we determined to learn something

about the subject for the benefit of those whose injury we had unwittingly assisted in.

It is my pleasure to-night to outline the course of study which was opened by this investigation. It was primarily necessary for us to define the exact function of a varnish in and on the coils or windings of a dynamo electric machine. Why should a varnish be used at all? Solely because there has never been an insulating fiber produced which did not need some sort of reinforcement which could obviously be best applied in the form of a paint or varnish. Motors will not run, even in very dry situations, unless some protection in the shape of varnish is applied. When we asked electricians for an explanation of this, they told us that water got into the machines if varnish was not used. When this answer was applied to street-railway motors running on submerged tracks, or on motors unprotected from street spattering, the explanation seemed to be adequate, but its adequacy was completely lost when we applied it to stationary machines running under fairly good conditions.

It is perfectly obvious that if an unpainted generator armature should be saturated with water and then started up at full speed with the brushes lifted from the commutator, the centrifugal motion in a few moments would force out all moisture, and that then the brushes could be brought into contact and the load assumed without danger.

Surely the insulation resistance of the varnish is not required to enable the machine to run. There probably never has been a successful machine designed wherein the difference of potential between windings was equal to 10 per cent. of the insulation resistance of the ordinary double-cotton covering which was used on those windings.

This covering has a resistance equal to about 200 volts a.c., and it is obvious that if that resistance could be made constant, there would be no necessity for the reinforcement of machine insulation with anything in the line of paint or varnish. In other words, any paint or varnish which is used on magnet coils is used in the hope of making constant the initial resistance of the cotton covering.

It being plain that the function of any varnish or paint

which is applied to a motor or dynamo coil is to reinforce the cotton covering, we must study the weaknesses of the cotton in order that we may know how to correct or help them.

The first defect of cotton is the fact that it cannot be spun to a commercial profit unless it carries from 5 per cent. to 15 per cent. of water; but at the same time our attention should not lose the fact that this water does not interfere with the average insulation value of cotton covering as indicated by mere laboratory tests. The trouble which the water makes is accomplished when it turns to steam under the heat of the machine or when it travels from the core out through the coil under the influence of rotary motion, leaving innumerable passages and openings where the electric current may follow.

Another material defect of cotton is the ease with which it becomes carbonized; but it is only fair to say that the carbonization of cotton covering is largely offset by the resistance gained from the expulsion of moisture as an armature becomes dried and seasoned.

The third defect of cotton is the acid which it carries and which assists its impregnation with copper oxide.

Determining that the best insulating material must be the one which would reinforce these weaknesses of cotton, we assembled all the materials commercially available for the manufacture of compounds which might be applied to coils of copper wire by dipping or with a painter's brush, and began the work of systematic search for the qualities which would enable these materials to accomplish the necessary results. In this connection every varnish gum, every treatment of drying oils, every combination of waxes, pitches, asphalts and gum substitutes, including the cellulose compounds, were brought under our tests.

The first test of all was to see whether a material had melting point or viscosity, or a combination of both, which would enable it to stay in a badly overheated coil. This point brought out a curious inability on the part of a good many electricians to distinguish a difference between old-fashioned tests and modern conditions.

They wanted to test insulation melting points by the same method by which oil chemists find the melting point of an oil or a wax, but we found that test so misleading as to make it necessary to make our tests exactly like the conditions of actual service. We wound a coil of double cotton-covered wire about a steel rod, saturated the coil with insulating compound, withdrew the steel rod, inserted in its place an ordinary thermometer, put current through the coil via water resistance, until the coil was so badly heated as to give off dense volumes of smoke, and if by weighing we found that a coil did not lose more than 10 per cent. of its compound, we decided that such material would stand hot service in overloaded machines. An insulating compound should have such a high melting point. The designer of a motor never can tell which one of his machines will be located in the hottest corner of a rolling mill, or whether his generator may not some day have to stand the heat of a torpedo boat engine-room with the ventilating apparatus broken down, or an emergency overload in ordinary practice.

The tests to determine the capacity of a given insulating material to exclude moisture from the coils of an idle machine were chiefly a process of elimination, and here we found aid from the experience of varnish and paint manufacturers, and in the researches which have been made concerning the materials which enter into their products.

We first eliminated shellac for the reason that it could only be made into a successful varnish by dissolving it in alcohol, or alcohol and water. You can make a shellac varnish totally devoid of water, but you cannot do it commercially, and if you could you could not keep it so, as the alcohol in shellac varnish rapidly attracts moisture the moment it is exposed or applied.

The copal varnishes and asphalt varnishes were eliminated at this point, as we found that the heat and vibration of magnet coils quickly reduced them to a powder, or cracked their films so badly that they could not exclude water any more than a sieve could hold it.

For some time we thought that linseed oil might be so

boiled that it would effectively exclude moisture. We were attracted by its high initial resistance and the extremely tough film which could be obtained from varnishes composed of it; but here again we were stopped by the accumulated facts which experienced varnish and paint makers furnished us.

Linseed oil is a commercial commodity solely because of the rapidity, as compared with all other oils, with which it absorbs oxygen. A method of arresting the oxidation of a film of linseed oil at any desired point would be of immense value to the electrical fraternity. We cannot hope to arrest the oxidation of a film of linseed oil at any particular point. It continues to oxidize until it becomes a brittle, cracked and utterly defenseless mass so far as its capacity to prevent the passage of any stray electric current is concerned. More electrical apparatus has been reconstructed or repaired because of the oxidation and other defects of linseed oil than of all other causes put together.

A great many electricians like to claim that their apparatus is well ventilated. "Well ventilated" also means well oxidized. There are very few armatures which are not well ozonized also.

When the wearer of a black coat leans against the white trimmings of a house which was painted with linseed oil and white lead last Spring he has to dust himself off, simply because the oil, which should have held the pigment to the house, has been totally destroyed by atmospheric action. It is because of this quality of linseed oil that we are compelled to have a varnishing day in our art galleries, and it has never been disputed that thoroughly oxidized linseed oil is not only soluble in water, but is hydroscopic, since that fact was established many years ago by eminent German authorities.

We had to consider that an insulating compound might be used some day in a generator located on top of a steel penstock in an isolated power-house, where there was no heat, and that when the generator should shut down it would attract moisture at a tremendous rate by condensation. It would not run a week under these conditions if it was insu-

lated with a linseed-oil preparation. It is well known that a series of chemical actions may take place in an electrical machine, wherein linseed oil may be found wholly responsible for the presence of water even before the oxidation of the oil has reached the advanced stage. This occurs when at atom of hydrogen in the oily acids of the varnish is replaced by an atom of copper. The ejected atom of hydrogen selects a pair of friends from the oxide on the wire and thus produces water. It is perhaps needless for me to say that only one material was able to pass these tests for the exclusion of moisture under practical conditions, that being the high-melting-point paraffin compound whose widely successful use has brought to me the honor of delivering this address.

A particular point which led us to the adoption of this material is its capacity to withstand high temperatures for a great length of time and still maintain its original plastic condition. The vibration in a high-speed armature probably equals that in any mechanical device when the shattering jars of gear connections are taken into consideration and when street railway machinery is added to the list of apparatus under consideration.

The expansion of armatures and field coils as they heat, and their subsequent contraction when the loads are removed, are obvious, and consequently any insulation which does not have permanent plasticity under heat is wholly defective for this sort of electrical insulation. Consequently a large list of materials, composed of varnish gums and linseed oil, asphalts, etc., were eliminated one by one as they showed their utter incapacity to stand the shattering influences of this vibratory stress.

The defectiveness of the first material which we ever made was caused wholly by the presence of varnish acid. As is well known to varnish chemists, all of the varnish gums are acid bodies. Indeed, it is safe to say that there is practically nothing in the shape of gum or oil which enters into varnish that is not an acid body.

The question then arose, "How far is anybody warranted in introducing acid into the vitals of high-cost apparatus?"

Of course the answer is, "Just as little as possible;" but I am sorry to say that a good many electricians have declined to give this point the consideration to which it is entitled, and they have thereby become responsible for a great deal of the apparatus which has proven defective.

Of course I am familiar with the claim of some electricians that they "never have any trouble with apparatus built by them." In the first place, we know that such a statement is not true; and if it was true, it would not be a good reason for deliberately disobeying physical law.

From one end of this country to the other you can go in the street-railway field and find apparatus which has gone to the scrap-heap chiefly because it has been insulated with defective insulation. Within a year one of the largest generators in the world has had its armature twice rewound because it was insulated with defective insulation, and on the third trial its builders repaired it with the same stuff which first short-circuited it. The money loss in that instance is already close to $10,000, with more to follow. There is not a central station manager in the United States who has tried to sell power who has not come into contact with a manufacturer or a machine-shop superintendent who told him he would not put in a motor unless the central station man would guarantee against his shut-down losses and against repairs. Printers have discarded electric motors for gas-engines because they say the gas-engines have a reliability which motors have not.

Every defective electric motor is an argument for the sale of an engine in its place, and it is only so because the motor manufacturers have neglected in their rush to keep up with commercial progress to give to their insulation the same care and thought which the engine builders have given to their construction. The same processes of elimination which keeps poor metal out of piston rods will keep poor insulation out of armature coils. But at present manufacturers will not seek such improvement until consulting and operating engineers insist upon it.

The obvious unfitness of linseed oil for motor insulation, because of its acid composition, is best explained by refer-

ence to indisputable authority. What everybody knows "is most indisputable authority," and anybody who knows anything about chemistry knows that an acid is a body which will attack metal. An acid is a body which attacks copper. An acid is a body which will combine with copper to produce a third and possibly a fourth material. Users of shellac, copal varnish and linseed-oil varnish as insulation have frequently found that the cotton covering of their wire has been turned a brilliant green, which is a universal symptom that the copper has been attacked by an acid.

When we said that such a symptom was a bad one, some electricians argued with us and said they didn't think we had any authority for that statement, and that it didn't make any difference if a coil did turn green, provided that coil was properly baked out. They declined to accept what every chemist knows.

We have given considerable thought to this matter, and have come to the conclusion that a green coil is an evidence of bad construction, is *prima facie* evidence that a radical chemical change has gone on within precincts whence chemical changes should be excluded with great rigor.

Green discoloration is evidence of inconstancy where constancy is indispensable. As it is very seldom seen except as a relic of a broken-down machine, it may therefore be said to be coincident with burned-out and short-circuited machines; but this discoloration becomes more potent in its suggestiveness as we consider what takes place to produce such a radical physical change—a change visible to the naked eye, a change positive and far-reaching enough to send the green coloring matter through mica $\frac{1}{16}$ of an inch thick and to impregnate thick wrapping-paper and fiber stock. In the study of this action we need accept nothing but the facts and authority which is beyond dispute by being common knowledge. When we see a piece of mica that was once a beautiful amber color turned green, when we find that it would stand a puncture strain of 10,000 volts while amber color and can be punctured with 1,000 volts since its color has been altered, and we find that it has actually failed to pre-

vent the passage of a current of not over 10 volts, we have a right to conclude that there is a relation between such green discoloration and coincident drop in insulation resistance; and we have a right to carry that conclusion a step further and decide that the short-circuit was caused by the chemical transformation of which the color change is evidence.

At least we are justified in a further exploration and examination in the light of the simplest variety of information on a simple chemical action. By so doing we find that it is easy for a varnish to have a chemical effect upon copper. Such action is the rule rather than the exception, and now, by reference to well-known authority, we find that this green action is the characteristic one of acids upon copper. The presence of acids near copper is always evidenced by green discoloration. Vegetable acids substitute atoms of copper for atoms of hydrogen in common with other acids. We are justified in concluding that such substitution of copper for hydrogen takes place in a gaseous or semi-gaseous state. We shall now be able to apply the knowledge that vaporized copper has a high conductivity, and we shall then come to an unassailable conclusion that during the time when that mica was being impregnated with that vapor or varnish-copper the insulation of the mica was so reduced that an easy passage was afforded to the 8- or 10-volt current which effected the short-circuit.

When we find that the green discoloration may take place in an idle machine and not short-circuit it, and that short-circuits always appear when the green discoloration takes place in a machine which has been constantly in operation, we obtain further proof of a positive nature that acids should not be permitted to enter into coil construction under any circumstances—not even when they are loaded with black coloring matter to cover up their corrosive action.

In this connection we exploded one of the Mother Goose melodies or superstitions of the electrical fraternity—the foolish notion that lubricating oil caused short-circuits. Lubricating oil never will, never did, it never can, cause a short-circuit. If we could design a generator which would

run in oil, immersed in oil just as transformers are built, we should undoubtedly produce a successful machine. Why then should lubricating oil cause a short-circuit?

The first electrician who had a short-circuited machine was naturally disappointed and wanted an excuse; and when he found that lubricating oil had penetrated into the coils, he accused it of causing the trouble. What actually occurred was this: the lubricating oil came in and stirred up the dormant or satisfied acids of the varnish which he had used. Varnish-makers who have essayed to manufacture insulating compounds have on several occasions claimed that their varnishes were oil-proof. This was nothing but a joke, however, and they never expected anybody to believe it. Varnish salesmen sometimes attempt to prove that an insulating varnish is oil-proof because they can coat a newspaper with it and the newspaper will hold oil in the open air and away from the heat of operating apparatus. As a matter of fact, varnish which is so proved to be oil-proof will unite readily with lubricating oil under a temperature of 150° F.

The trouble is, that it will not unite homogeneously. The oil unites with one part of the varnish and separates that part from the remainder of the varnish, so that there are two or three separate and distinct bodies where there was originally but one. In one or both of these the acids are now unsatisfied and they immediately attack the copper, and, as before described, cause the short-circuits which were attributed to lubricating oil.

The oil was absolutely innocent. It is absolutely indispensable, and the acids of acid insulations are not indispensable.

Inasmuch as it is feasible, by working in the paraffin series, to make non-acid insulating compounds which have complete chemical affinity for lubricating oil, it is perfectly easy to obtain insulation for a machine which will be friends with and welcome all the good insulation which may soak into it from its bearings in the form of oil.

IRON AND STEEL TRADE IN 1902.

The report, now in press, on the iron and steel trade for 1902, by Mr. James M. Swank, United States Geological Survey, shows a continued advance in the annual domestic production of pig iron, the excess over 1901 being 1,942,953 tons, or almost 12·24 per cent. The total production in 1902 was 17,821,307 long tons, as compared with 15,878,354 tons in 1901, 13,789,242 tons in 1900, 13,620,703 tons in 1899, 11,773,934 tons in 1898, and 9,625,680 tons in 1897.

Notwithstanding this increase of production, the imports of iron and steel in various forms amounted in foreign value in 1902 to $41,468,828, as against $20,395,015 in 1901, an increase in 1902 of $21,073,811, or over 100 per cent. The total exports of iron and steel, including locomotives, car wheels, machinery, etc., amounted in 1902 to $97,892,036, as against $102,534,575 in 1901, $129,633,480 in 1900, $105,690,047 in 1899. The exports of agricultural implements, which are not included above, amounted in 1902 to $17,981,497, against $16,714,308 in 1901.

The consumption of pig iron in 1902 was approximately 18,439,899 long tons, of which 625,383 tons were imported, as compared with 16,232,446 tons in 1901, of which 62,930 tons were imported. The increased production of pig iron in 1902 over 1901 was 1,942,953 tons; the increased consumption was 2,207,453 tons.

At the close of 1902 the number of furnaces in blast was 307, as compared with 266 at the close of 1901 and 232 at the close of 1900. At the close of 1902 105 furnaces were out of blast—many being temporarily banked from lack of fuel—as against 140 furnaces at the close of 1901.

The production of Bessemer steel ingots and castings increased more than half a million tons in 1902—to 9,306,471 long tons; the production of Bessemer steel rails remained almost stationary. The production of open-hearth steel ingots and castings in 1902 was 5,687,729 long tons, an increase of 1,031,420 tons over 1901.

In the fiscal year 1902 there were built for mercantile service 106 steel vessels and one iron vessel, with a gross tonnage of 280,362 tons, as compared with 119 steel vessels and one iron vessel, with a gross tonnage of 196,851 tons, built in 1901. Of these 107 vessels, 49, with a gross tonnage of 161,930 tons, were built at ports on the Great Lakes.

The production of pig iron in Canada in 1902 increased to 319,557 long tons, over 30 per cent. as compared with 1901; and the production of steel ingots and castings in 1902 was 182,037 long tons, as compared with 26,084 tons in 1901, an increase of 155,953 tons, or nearly 600 per cent.

The second part of Mr. Swank's report consists of an interesting and valuable series of tables presenting complete statistics of the production of iron and steel, iron ore and coal in the United States, Great Britain, Germany, France and Belgium, to the close of 1901, thus showing the progress that has been made by these countries in the first year of the twentieth century.

PHYSICAL SECTION.

Read by title at the Stated Meeting held May 21, 1903.

On Convergents and Arithmetical Series, the Ratio of Whose Terms Approximate Successively the Value of π; and on Their Application to the Construction of Computing Machines.

By F. L. O. Wadsworth.

Several years ago I had occasion to make use of a complicated reduction formula, the numerical application of which involved the frequent use of a value of π accurate to the sixth decimal place. In order to avoid the continued manipulation of the large number of figures which this necessitated, I substituted for the decimalized value a ratio between two whole numbers, P and Q, so chosen as to express this value to the required degree of accuracy. These numbers are easily found by the method of convergents. For the value of π required, *i. e.*, $\pi = 3{\cdot}1415927$, this gives

		c	Δ
$\frac{P}{Q} \doteq C_1 = \frac{3}{1}$	$= 3{\cdot}0000000$	3	$141592{\cdot}7 \times 10^{-6}$
$\doteq C_2 = \frac{22}{7}$	$= 3{\cdot}1428571$	7	$1264{\cdot}4 \times 10^{-6}$
$\doteq C_3 = \frac{333}{106}$	$= 3{\cdot}1415094$	15	$83{\cdot}3 \times 10^{-6}$
$\doteq C_4 = \frac{355}{113}$	$= 3{\cdot}1415929$	1	$\cdot 2 \times 10^{-6}$
$\doteq C_5 = \frac{126003}{40108}$	$= 3{\cdot}14159269+$	354	$\cdot 01 \times 10^{-6}$
$\doteq C_6 = \frac{252361}{80329}$		2	
$\doteq C_7 = \frac{1640169}{522082}$		6	

	c	Δ
$\doteq C_8 = \frac{1892530}{602411}$	1	
$\doteq C_9 = \frac{9210289}{2931726}$	4	
$\doteq C_{10} = \frac{11102819}{3534137}$	1	
$\doteq C_{11} = \frac{31415927}{10000000} = 3{\cdot}1415927$	2	$0{\cdot}0000 \times 10^{-6}$

The terms c and Δ of the above series denote respectively the "components" of the continued ratios and the differences between the successive convergents and the required value. The relations between the quantities C_1, C_2, ... C_n are expressed by the well-known equation

$$C_n = \frac{P_n}{Q_n} = \frac{C_n P_{n-1} + P_{n-2}}{C_n Q_{n-1} + Q_{n-2}} \qquad (1)$$

The remarkable characteristics of this particular series of convergents is the very rapid decrease in the value of Δ for the first four terms of the series. The third convergent, C_3, of the series expresses the correct value of π to within one unit in the fourth decimal place, *i. e.*, to within 1 part in about 38,000; the fourth convergent, C_4, expresses the required value to within 2 parts in the *seventh* decimal place, or to within 1 part in about 15,000,000. It is very unusual that an incommensurable number such as π can be expressed with this degree of accuracy by a ratio between two numbers, each consisting of only three figures.

The third convergent, C_3, expresses the value of π to the degree of accuracy usually necessary in computations. For such purposes it is, however, just as easy to employ the fourth convergent, C_4, which is of exactly the same order of magnitude as C_3. The same statement applies to the use of these ratios in computing machines and mechanical solutions of equations involving this constant. In the latter operations, however, we can frequently employ with advantage a ratio which is less accurate and involves fewer numbers than C_3, but which must be more accurate than the

next lower convergent, C_2, whose error is about 1 part in about 2,400. This led me to search for other ratios intermediate both in order and accuracy to $C_2 - C_3$, and to the discovery of the arithmetical series which it is the first purpose of this paper to describe.

It will be noted that the "component" or approximate ratio, c_4, of the fourth convergent is unity. From (1) it follows, therefore, at once that

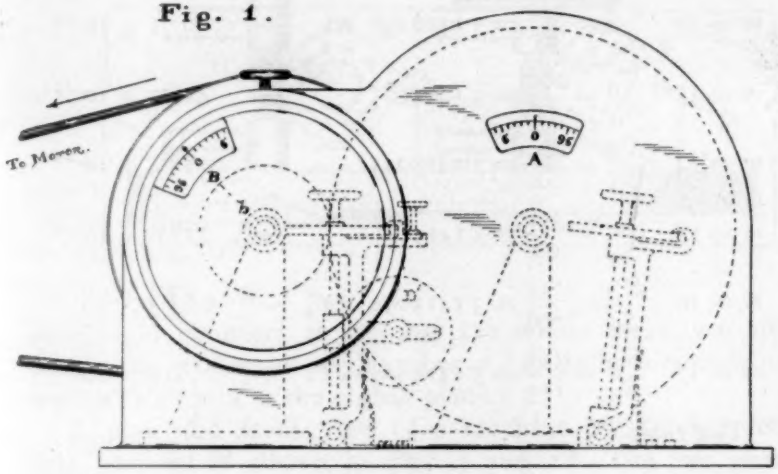
$$P_4 = P_3 + P_2$$

and

$$Q_4 = Q_3 + Q_2$$

That is, both terms of the convergents C_3 and C_4 are members of arithmetical series whose common differences are the corresponding terms, 22 and 7, of the convergent C_2.

Fig. 1.



This suggested to me the probability of the lower terms of the same series forming ratios which would be intermediate in value between the convergents C_3 and C_4 and the convergent C_2. This was found to be the case. The two series are

$$S = 1 + 8 + 15 + 22 + \ldots 106 + 113 + 120, \text{ etc.}$$

$$S' = 3 + 25 + 47 + 69 + \ldots 333 + 355 + 377, \text{ etc.}$$

The successive values of the ratios

$$\frac{S'_m}{S_m}$$

are

			Δ_m
$m = 1$	$\frac{S'_1}{S_1} = \frac{3}{1}$	$= 3{\cdot}000000 = C_1$	$-141592{\cdot}7 \times 10^{-6}$
$m = 2$	$\frac{S'_2}{S_2} = \frac{25}{8}$	$= 3{\cdot}125000$	$16592{\cdot}7 \times 10^{-6}$
$m = 9$	$\frac{S'_9}{S_9} = \frac{179}{57}$	$= 3{\cdot}1403509 \doteq C_2$	$-1241{\cdot}8 \times 10^{-6}$
$m = 10$	$\frac{S'_{10}}{S_{10}} = \frac{201}{64}$	$= 3{\cdot}1406250$	$-967{\cdot}7 \times 10^{-6}$
$m = 11$	$\frac{S'_{11}}{S_{11}} = \frac{223}{71}$	$= 3{\cdot}1408451$	$-747{\cdot}6 \times 10^{-6}$
$m = 12$	$\frac{S'_{12}}{S_{12}} = \frac{245}{78}$	$= 3{\cdot}1410256$	$-567{\cdot}1 \times 10^{-6}$
$m = 13$	$\frac{S'_{13}}{S_{13}} = \frac{267}{85}$	$= 3{\cdot}1411765$	$-416{\cdot}3 \times 10^{-6}$
$m = 14$	$\frac{S'_{14}}{S_{14}} = \frac{289}{92}$	$= 3{\cdot}1413043$	$-288{\cdot}4 \times 10^{-6}$
$m = 15$	$\frac{S'_{15}}{S_{15}} = \frac{311}{99}$	$= 3{\cdot}1414141$	$-178{\cdot}6 \times 10^{-6}$
$m = 16$	$\frac{S'_{16}}{S_{16}} = \frac{333}{106}$	$= 3{\cdot}1415094 = C_3$	$-83{\cdot}3 \times 10^{-6}$
$m = 17$	$\frac{S'_{17}}{S_{17}} = \frac{355}{113}$	$= 3{\cdot}1415929 = C_4$	$+0{\cdot}2 \times 10^{-6}$

The ratio

$$\frac{S'_9}{S_9}$$

is very nearly equal to C_2. Any desired degree of approximation to the value of π between C_2 and C_4 may be secured by choice of a suitable value of m from the above table. Thus, for a degree of approximation of 1 part in 10,000 we select the ratio for which $m = 14$, *i. e.*,

$$\frac{S'_{14}}{S_{14}} = \frac{289}{92}$$

This ratio is sufficiently accurate for all ordinary computations and mechanical solutions, and involves one less figure than either the ratios C_3 or C_4.

GRAPHICAL AND MECHANICAL COMPUTATIONS.

The very accurate representation of the value of π by the simple ratios just found enables us to readily obtain the circumference of any circle whose diameter is given, or, *vice versa*, by means of an ordinary slide rule, or, better still, by a simple gearing. If we gear together two wheels which contain respectively 355 and 113 teeth, the angular motion of the second will be π times that of the first. If we add two dials divided into the same number of parts and two

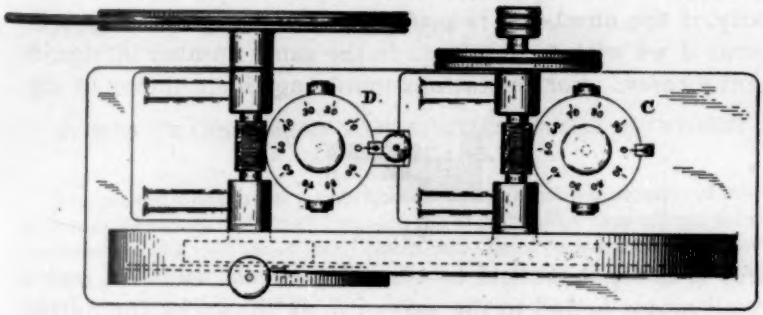


Fig. 2.

revolution counters to register the whole turns, we can obtain the product of any number of figures by π correct to within two units in the eighth place.

A plan and front view of a machine constructed for this purpose is shown in *Figs. 1* and *2*.* The two gear wheels are 48 pitch, and are therefore 7·396″ and 2·354″ pitch diameter respectively. They are provided with dials, each about 4″ in diameter, divided into 500 parts graduated from 0 to 100. The revolution counters are two worm

* I have been unable to find the original drawings, and as the machine itself is not now in my possession, the general details of the device are drawn from memory and may not exactly correspond to those of the original construction. They are, however, essentially the same.—AUTHOR.

wheels, each having 100 teeth driven by worms on the axes of the two gears. With well-cut gears the error due to irregular spacing, roughness in the teeth, etc., etc., does not exceed 2 per cent. of the tooth space. The accuracy of the ratio between the readings of the two dials can therefore be relied upon to within $\frac{1}{10}$ of a division, *i. e.*, to $\frac{1}{5000}$ of a revolution. If, therefore, we demand an accuracy of 1 part in the seventh decimal place, *i. e.*, $\frac{1}{30000000}$ of the value of π, we must revolve the driving gear A at least 200 times. Thus, if the number x, whose product by π is desired is 10,254, $10\frac{254}{1000}$ turns of the dial and gear A will give the product πx on the dials of gear B to 1 part in 50,000; $102\frac{54}{100}$ turns of A will give the product πx to 1 part in 500,000; and $1{,}025\frac{4}{10}$ turns, the product πx to 1 part in 5,000,000. Similarly, if the number x is 495687·3, we must give A $495\frac{6875}{1000}$ turns if we wish to obtain πx to the same number of significant figures. For operations involving this number of fig-

Fig. 3.

ures it is inconvenient to turn the wheels by hand, and a small motor belted to the axis of B, as shown by the dotted lines, is provided for this purpose. The motor is, of course, stopped just before the final reading is reached and the operation completed by hand. In order to return the readings to zero for another operation, the worms C and D may be lifted out of engagement with their respective axes, as shown by the dotted lines of *Fig. 1*, and the index mark of wheel B adjusted and clamped at any point on the circumference of its respective dial. The index mark of D is correspondingly adjustable over a space of 1 division, so that there may never be any uncertainty as to the whole number of revolutions indicated by D.

With this machine it is possible to obtain the product of any given number of 8 places or less by π much more easily and quickly than it can be done by the use of logarithms or by any of the usual forms of calculating machines.

For less accurate work a much smaller instrument can be constructed by using the ratio S_{14}, making the gears of finer diametrical pitch and omitting the revolution counters *C* and *D*. Greater compactness can also be secured by using, instead of external gears, two concentric internal and external gears of 289 and 92 teeth respectively, connected by idler gears. The reading dials can be placed on opposite sides of the small circular case containing the whole. In this way, using gears of 128 pitch, an instrument of about $2\frac{1}{2}$ inches diameter and $\frac{1}{2}$ inch thick, or about the size of an old-fashioned watch, can be made. This is small enough to be readily carried in the pocket and will enable a machinist to mechanically rectify, or, if desired, "square" a circle of any given diameter with an accuracy of 1 part in 10,000.

ALLEGHENY OBSERVATORY, April, 1903.

POWER-TRANSMISSION POSSIBILITIES IN THE SOUTHERN APPALACHIANS.

The present commercial possibilities in the electrical transmission of power over long distances with small loss, and the opportunities thus offered for the combination of a number of small plants into one of considerable magnitude, serve to direct attention to a number of water powers in the Southern States which are now totally ignored.

The popular idea of an available water-power is a moderate fall on a stream of considerable size, located within a few yards of a railroad. Like many popular ideas, it is only partly correct. The power which can be obtained at any power site on a stream is the product of the weight of the water passing the site per unit of time multiplied by the height of the perpendicular fall obtainable, and for the same total power these quantities vary inversely; that is, if the head be doubled, the quantity of water may be diminished by a half and the resultant power will be the same; if the head be multiplied by ten, then one-tenth the quantity of water will yield the power, and so on, in similar ratio.

Given a sufficient fall, therefore, a small amount of water may be made to furnish a very large amount of power, and, in point of fact, many of the large power developments of the Western States are of this type, the quantity of water used being small, but the head being measured by hundreds of feet. The distance between the points where the power is developed and where it is to be utilized is annihilated by electrical transmission.

A large number of streams in that part of the Southern States in which the Appalachian Mountain system attains its maximum development have their sources far up on the mountain slopes, in regions of great rainfall and of large

and permanent run-off, and these, in their courses to the valleys below, often fall hundreds of feet within short distances. By the application of proper methods these streams are capable of furnishing and transmitting power in considerable quantity at comparatively small cost, certainly in many instances at less cost per unit of power obtained than would be possible on the large trunk streams, and without the attendant risks.

The flow of many of these streams, now unused and indeed ignored, has been measured by the engineers of the United States Geological Survey, and the results have been published in the series of Water-Supply and Irrigation Papers.

LIFE OF ENGLISH LOCOMOTIVES.

An English lecturer recently stated the average life of an English express locomotive to be 25 years; of a local passenger engine, 25 years; of a freight locomotive, 26 years, and of a switching engine, 27 years. The total mileage of an express passenger engine was placed at from 700,000 to 1,000,000 miles; and for each of the other classes of engine a mileage of 500,000 to 800,000 was given. In the United States, the average life of an express locomotive was given as 18 years; of a local passenger engine, 19 years; of a freight engine, 16 years, and of a switch engine, 22 years. Whereas the mileage of an English express locomotive was only at the outside 1,000,000 miles in 25 years, or 40,000 per year; in the United States it is often as high as 2,000,000 miles, or 110,000 miles per year.—*Iron Age.*

PROFESSOR BELL'S KITE EXPERIMENTS.

The final paper read before the last meeting of the Academy of Sciences was "On the Tetrahedral Principle in Kite Structure," by Alexander Graham Bell. At the outset he said that in the old Hargrave box kite, and all subsequent kites and flying machines of the same order, there were two important defects, which he described as follows: The box kite is braced in a horizontal and vertical direction, but not otherwise, so that cross supports have to be introduced in the frame, which increase the weight without adding to the flying power, and at the same time operate as an obstacle to the wind. The chief defect of the box kite, of which Dr. Langley's aerodrome is an elaboration, is that the weight increases with the cube as rapidly as the lifting power does with the square, so that the larger the kite, the less it will lift in proportion. In view of these facts, he had been led, he said, to construct a kite, the frame of which would present the form of a triangle no matter from what side one viewed it. In other words, the frame was a perfect tetrahedron; and in experimenting with the same, he found, as he had expected, that it was self-braced in every direction, and moreover, that the lifting power increased at a greater ratio than the increase in weight. He was, furthermore, surprised at the facility with which such a kite could be managed. By combining a great number of these kite tetrahedrons he had recently built up an immense kite, with which he successfully lifted not only a man, but a weight of 200 pounds, showing the vast improvement of this over all previous machines of the same order.

Mechanical and Engineering Section.

Stated Meeting, held April 16, 1903.

Fuel Oil.

By John F. Rowland, Jr.

Under the conditions of using a triple expansion engine, a horse-power hour may be obtained for a pound and a-half of coal per hour, and if the boilers, engine and condenser be properly looked after, this result is continuously possible, using the average grade of either anthracite or bituminous coal.

It may be either from the impossibility of using steam in this multiple expansion manner because of the smallness of the unit, or the undesirability on account of the difficulty or expense of obtaining condensing water, that power is had from the expansion of steam in a single cylinder without a condenser.

The endeavor to obtain from this latter condition the best possible economy has resulted in the numerous devices for supplying coal to a boiler in a mechanical manner, both in the natural and pulverized forms.

There has been supplied in the same natural manner another form of combustible than coal, which is the subject of this evening's discussion, viz., oil.

For many years refined oils have been used as fuel where the greater heat value alone determined the selection, but its use in large quantities where it has replaced coal is confined to such as is found in the natural state.

There are about 19,000 heat units in a pound of oil, and about 12,000 available ones in a pound of coal.

In comparing the two fuels, it is not alone the difference in heat value per pound that must be considered.

There are objections to the use of coal which would make oil the more desirable fuel if the heat values were the same, provided the cost of oil allowed the selection.

In the ordinary way of firing coal there is the opening and shutting of the fire door with the constant change of temperature and the effect of this change upon the furnace, the combustion chamber and tubes in an internally fired boiler, and upon the shell or tubes in an externally fired one.

It is from the effect of this change that most of the deterioration in boilers is due, and most of the expense of upkeep is entailed.

The deposition of soot on the tubes of a boiler constitutes perhaps the greatest heat waste in burning coal, and coal can hardly be burned in a manner to prevent this. Until the ashes from the burning of coal are removed from the vicinity of a boiler, there is a constant deterioration of any metal with which they come in contact.

It is possible, in burning oil, to dispense entirely with the temperature changes, there are no ashes to remove, and careful burning of the oil leaves very little unburned carbon.

The burning of oil entails a minimum of expense for operating.

The oil may be burned with the use of either steam or air, or a combination of the two, to atomize it and to provide sufficient oxygen for combustion.

In selecting an oil burner that uses steam to atomize the oil, care must be taken that the quantity of steam be not too great a percentage of the total amount generated.

If the plant where oil is burned uses pneumatic tools, it may be more advantageous to use air.

Where a forced draft system of combustion is used, a combination of steam for atomizing and air for combustion may be used, and this combination gives results that have probably not been exceeded for economy.

In a plant of over 4,000 horse-power, using steam to atomize the oil and air at a pressure of 3 inches of water for combustion, there is obtained regularly a net evaporation of 14·1 pounds of water from and at 212° per pound of oil. The tubes are sponged in this plant once a month, as against every day when coal was used, and no repairs

to furnaces or tubes have been necessary after seven months.

There is a considerable difference in the price of oil, depending on the distance it has to be carried, and while the price may be prohibitive where the distance is great, the fact remains that oil is largely superseding coal as a fuel, and when the economy of operation where oil is used has been continued for a sufficiently long time to have the results studied and diffused, there is no question but that oil will be still more generally used as a fuel.

ELECTRICITY ON THE ELEVATED RAILWAYS OF NEW YORK.

The substitution of electricity for steam upon the elevated railways of New York has proved a great success, not only in the direction of economy but in accelerating the speed, which on a railway of the kind in question is a matter of the greatest importance. The *Scientific American* asserts that the electrical horse-power employed amounts to 45,000, which is far above the average steam-power in use formerly. The average speed is not only increased, but more cars can be hauled by 25 per cent. and the average number of passengers carried daily is 800,000. The greatest tractive effort exerted upon a train is now 20,000 pounds, where the motors are distributed throughout the train, each car being available for adhesion; but when locomotives were employed the utmost traction on the draw bar was only 7,000 pounds. The service has been so improved that the time between terminals has been reduced 25 per cent., so that with the same headway it is possible to run 25 per cent. more trains than with the steam service. In the matter of cleaner service, absence of noise, abolishment of dripping oil and hot water, there is no comparison between the steam and the electric systems.

ARTIFICIAL GRAPHITE.

The manufacture of artificial graphite has assumed a very prominent position in the graphite industry in recent years, the production in 1902 amounting to 2,358,828 pounds, as compared with 2,500,000 in 1901 and 860,750 pounds in 1900. The production of both the crystalline and amorphous variety has been steadily developed by the sole producers, the International Acheson Graphite Company, at Niagara Falls, N. Y., who began their operations in 1897 with a product of 162,382 pounds. The decrease in unit value of the total production from 8 cents per pound in 1899 and 1900 to 4·75 cents per pound in 1901 and 4·69 cents per pound in 1902 was largely due to the increased proportion of the amorphous variety produced. The output of 1902 consisted of 885,591 pounds of graphitized electrodes and 1,475,237 pounds of artificial graphite in the granular or powdered form. The electrodes were used in electrolytic processes for the production of caustic soda and of chlorine and metals in

chloride solution; also in electro-metallurgical processes, such as the production of calcium carbide, the electric smelting of copper and iron ores and the manufacture of various iron alloys. The artificial graphite in the form of grains and powders was used chiefly in the manufacture of paint, dry batteries and commutator brushes, although a considerable quantity was used in the manufacture of lubricants, in electroplating work, and in certain chemical processes requiring a carbon of exceptional purity.—*Iron Age.*

MACARONI WHEAT.

The success of macaroni wheat in this country is a matter of great importance to grain growers. It has been demonstrated that not only is the yield greater than common wheat, but it brings a much higher price and thrives in localities where ordinary wheat fails or gives but a scant yield. In South Dakota, where the experiments were carried on, from 60 to 120 per cent. more macaroni wheat was grown than that given by the blue stem or Fife wheat, and where 150,000 acres were sown with it last year, 300,000 are under cultivation this year. Last year was an unfavorable one for this variety, much of the crop being injured by rain and sleet. In spite of this the yield was 80 per cent. greater than the regular crop. Macaroni mills abound in Minnesota, Dakota, Pennsylvania, and New York. To keep them going, thousands of bushels of macaroni wheat were imported; even with this they were compelled to use bread wheat to some extent, which results in a lower grade of goods. This high-grade wheat makes far better and more palatable bread than that generally used, so it will be in demand for that class of work. It is stated by Professor Carleton, the macaroni expert in this country, that the wheat crop can be increased 50,000,000 bushels readily by more attention to the subject.—*Iron Age.*

LARGEST BLOWN GLASS BOTTLES.

On May 9th the largest glass bottles ever blown were made at the plant of the Illinois Glass Company for exhibition at the World's Fair. The capacity of each bottle is 45 gallons. It was not until after many unsuccessful attempts that the bottles were made. Four perfect bottles were produced. Each stands near 6 feet high and measures about 16 inches across the bottom. The men who blew the bottles each supplied about 11,000 cubic inches of air. —*Iron Age.*

SALAMANDERITE—A NEW PRODUCT FROM ASBESTOS.

One of the latest of the asbestos discoveries has received the name of "Salamanderite." Besides being thoroughly fire-proof, it can be made to duplicate any decorative effect obtainable by the finest cabinet work in the costliest woods, or by tiling, and at a small percentage of the cost of the genuine article. It may be finished in exact fac-simile of quartered oak, mahogany, maple or any fancy cabinet woods, either plain or in the finest marquetry or bas-relief effects, indistinguishable from the most costly work, so says a recent prospectus. Its value for churches, theatres, steamships, residences and other structures is obvious.—*Iron Age.*

CHEMICAL SECTION.

Stated Meeting, held January 29, 1903.

The Census of Manufactures of 1900.

By Charles E. Munroe.

(*Concluded from p. 48.*)

Wherever the card catalogue revealed the failure or neglect of an enumerator or special agent to secure a return for an existing establishment, the attempt was made to obtain it by correspondence, often successfully. In the case of some very large establishments thus overlooked, it was necessary to send a special agent directly to the establishment in order to secure a return. In many instances the failure to secure a return on the first canvass was due to the fact that the manufacturing establishment was located beyond the city limits and fell, therefore, within the jurisdiction of enumerators who neglected it. The growing tendency of manufacturing establishments to locate at points convenient to a great city, but outside its corporate limits, increases the difficulties of a thorough canvass of manufactures, which can be fully overcome only by the use of the card catalogue just described. Another difficulty arose from the tendency to render the factory report from the city office as if the operations were carried on at the office. Thus in my own topic returns received made it appear that an industry which produces much dirt was being conducted in one of our most sumptuous office buildings and that many fertilizer factories were located on high-priced property in one of the busiest thoroughfares. The incongruity of these returns led to an investigation, which revealed the fact that not only were the factories not located at the places given, but that in some instances they were not even in the city or the State returned, but in an adjacent State. Such errors were not uncommon in the first returns, but they were serious and had to be corrected; for, as legis-

lation upon public and local interests for a considerable term of years will be guided largely by the statistics of this census, it was essential to make the returns as exact as possible, particularly as regards location.

In drafting the schedules a general schedule embodying the interrogatories required by the Act and common to all industries was prepared. This general schedule was an improvement over the similar schedule used at the previous census, in that it was printed upon four pages instead of eight, and contained detailed instructions as to the manner in which the answer to each question should be enacted. Any enumerator, special agent or manufacturer, at all in doubt as to the nature of the information desired in response to each question, had merely to turn to the last page for his instructions. The special schedules contained the same interrogatories as the general schedule, but with certain of them in a more expanded form and with greater detail as prepared by the expert special agents to fit the particular selected industry that the agent was detailed to treat of.

The general schedule called for:

[Page 1.]

7—469.

TWELFTH CENSUS OF THE UNITED STATES.

SCHEDULE No. 3.—MANUFACTURES.

State . . . . . Supervisor's District No. . . . . .

County . . . . . Enumeration District No. . . . .

Collected by me on the . . . . . day of . . . . . , 1900.

. . . . . *Special Agent or Enumerator.*

Name of establishment . . . . . .

Name of corporation, firm, or individual owner . . . . . .

Location of factory or shop: { City or town . . . . . / Street and No. . . . . }

Post Office . . . . . .

(Manufacturing establishments operated by the same corporation, firm, or individual, and located in different towns or cities, must be separately reported.)

DEPARTMENT OF THE INTERIOR.

CENSUS OFFICE.

Washington, D. C., June 1, 1900.

The information returned on this schedule should cover the business year of the establishment most nearly conforming to and preceding the census year, which ends June 1, 1900.

All answers will be held absolutely confidential. No publication will be made in the census reports disclosing the names or operations of individual establishments in any particular. Special agents and enumerators of the census are liable to a penalty of $500 if they disclose any information obtained in their official capacity.

WILLIAM R. MERRIAM,
Director of the Census.

Extract from Act of Congress, March 3, 1899:

SECTION 22.—* * * "And every president, treasurer, secretary, director, agent, or other officer of every corporation, and every establishment of productive industry, whether conducted as a corporate body, limited liability company, or by private individuals, from which answers to any of the schedules, inquiries, or statistical interrogatories provided for by this Act are herein required, who shall, if thereto requested by the director, supervisor, enumerator, or special agent, willfully neglect or refuse to give true and complete answers to any inquiries authorized by this Act, or shall willfully give false information, shall be guilty of a misdemeanor, and upon conviction thereof shall be fined not exceeding ten thousand dollars, to which may be added imprisonment for a period not exceeding one year."

CERTIFICATE.

This is to certify that the information contained in this schedule is complete and correct to the best of my knowledge and belief.

. . . . . .

(Signature of the person furnishing the information.)

[Page 2.]

CAREFULLY READ AND FOLLOW INSTRUCTIONS ON PAGE 4.

(1) Date when this establishment commenced operations . . . . . .
Date when present management commenced operations . . . . . .

---

(2) Character of organization, whether individual, corporation, or other form (see instruction 2).

. . . . . .

---

(3) Character of industry, kind of goods made or work done (see instruction 3).

. . . . . .

. . . . . .

---

(4) Capital invested—owned and borrowed (see instruction 4).

Land	$
Buildings	
Machinery, tools and implements	
Cash on hand, bills receivable, unsettled ledger accounts, raw materials, stock in process of manufacture, finished products on hand and other sundries	
Total capital	$

(5) Persons employed (see instruction 5).

CLASSES.	Greatest number employed at any one time during the year.	Least number employed at any one time during the year.	Total amount paid in wages or salaries during the year.
Proprietors and firm members:			
Men			$
Women			
Salaried officers of corporation			
General superintendents, managers, clerks and salesmen:			
Men			
Women			
All other employees, including pieceworkers:			
Men, 16 years and over			
Women, 16 years and over			
Children, under 16 years			
Total			

AVERAGE NUMBER EMPLOYED DURING EACH MONTH.

(Wage-earners only, including pieceworkers. Do not include proprietors, firm members, officers, superintendents, managers, clerks or salesmen.)

MONTH.	Men 16 years and over.	Women 16 years and over.	Children under 16 years.	MONTH.	Men 16 years and over.	Women 16 years and over.	Children under 16 years.
January				July			
February				August			
March				September			
April				October			
May				November			
June				December			

(6) Months in operation:

On full time . . . . . ; on three-fourths time . . . . . ; on half time . . . . . on one-fourth time . . . . . ; idle . . . . . .

[Page 3.]

(7) Materials used (see instruction 7).

KINDS.	Unit of Measure.	Quantities.	Cost, not Including Freight.
Purchased in raw state—			
. . . . .	. . . . .	. . . . .	$ . . . . .
. . . . .	. . . . .	. . . . .	. . . . .
. . . . .	. . . . .	. . . . .	. . . . .
. . . . .	. . . . .	. . . . .	. . . . .
. . . . .	. . . . .	. . . . .	. . . . .
Purchased in partially manufactured form			
. . . . .	. . . . .	. . . . .	. . . . .
. . . . .	. . . . .	. . . . .	. . . . .
. . . . .	. . . . .	. . . . .	. . . . .
. . . . .	. . . . .	. . . . .	. . . . .
Fuel			. . . . .
Mill supplies			. . . . .
All other materials			. . . . .
Total cost of all materials			. . . . .
Amount of freight, if any, paid on the above			. . . . .

(8) Miscellaneous expenses (see instruction 8).

ITEMS.	Amounts.
Amount paid for rent of works, if any	$ . . . . .
Amount paid for rent of power and heat	. . . . .
Amount paid for taxes, not including internal revenue	. . . . .
Amount paid for rent of offices and for interest, insurance, internal revenue tax and stamps, ordinary repairs of buildings and machinery, advertising and all other sundries not reported under the head of materials	. . . . .
Total miscellaneous expenses	. . . . .
Amount paid, if any, for contract work	. . . . .

(9) Goods manufactured (see instruction 9).

KINDS.	Unit of Measure.	Quantities.	Value or Price at Shop or Factory.
			$
All other products			
Amount received for custom work and repairing			
Total value of all products			
Value of manufactured products for *preceding* business year			

[Page 4.]

(10) Power.

a. Power owned—

CLASS.	Number.	Horse-power.
Engines: Steam		
Gas and gasoline		
Water wheels		
Electric motors		
Other power (specify kind)		

(*b*) Power supplied to other establishments, if any—
Horse-power . . . . . .

(*c*) Power supplied by other establishments, if any—
Kind of power . . . . . ; horse-power . . . . . .
Name and address of establishment supplying same . . . . . .

INSTRUCTIONS.

All entries must be made clearly and neatly in ink. Amounts and values must be obtained from book accounts, if such accounts are available. Each question is to be answered. If any question is found not applicable and no amounts are reported, write the word "None."

Give, on page 1, the name, location, street and number, and post-office address of the establishment, and obtain the signature of the person furnishing the information. If the post-office address of the business office is at a different place from that of the plant, give both.

If a mercantile, mining, quarrying, or other business is carried on in connection with manufacturing, the capital, employees, wages, expenses, products, etc., reported must pertain only to the manufacturing.

INQUIRY 2.—*Character of Organization:* State whether the business is conducted by an individual, firm, limited partnership, co-operative association, incorporated company, or in some other form.

INQUIRY 3.—*Character of Industry:* Describe specifically the character of the industry and the kinds of goods manufactured or work done, as, for example, cut nails, chairs, leather belting, brooms, baskets, men's clothing, carpentering, blacksmithing, boot and shoemaking and repairing. Obtain and return with the schedule a card or other printed matter that describes the business.

INQUIRY 4.—*Capital Invested:* The answer must show the total amount of capital, both owned and borrowed. All the items of fixed and live capital may be taken at the amounts carried on the books. If land or buildings are rented, that fact should be stated and no value given. If buildings are both owned and rented, the fact should be stated, and only the value of the owned property given. The value of all items of live capital, cash on hand, bills receivable, unsettled ledger accounts, value of raw materials on hand, materials in process of manufacture, and finished products on hand, etc., should be given as of the last day of the business year reported.

INQUIRY 5.—*Persons Employed:* Account for all persons engaged in the business, both in the management and in production. Give the total salaries and wages paid, which should include board or rent furnished as part compensation. Give the number of proprietors and firm members, and, if they are not paid salaries, so state on the schedule. Stockholders of corporations are not to be reported unless they are salaried officials. Amounts paid for outside contract work must not be included in the wages, but be reported in answer to Inquiry 8.

INQUIRY 6.—*Months in Operation:* The entire twelve months of the year should be accounted for, as, for example, twelve months on full time; or eight months on full time and four months on half-time; or ten months on full time and two months idle.

INQUIRY 7.—*Materials Used:* The actual cost of all materials used during the year must be reported. Give the cost, exclusive of freight charges, and then the total freight paid. If this is not practicable, give the cost including the freight charges, and state that such charges are included. Name the principal materials and give the cost of each. Quantities should be given when possible, and the unit of measurement stated, as "pounds," "tons," "bushels," "feet," "yards," etc. Under the head "Purchased in raw state" give the name and the cost of such articles as raw cotton, iron ore, clay, or other materials that have had no manufacturing forces expended upon them, which enter the factory in a crude state. Under the head "Partially manufactured" give the name and the cost of all partially manufactured articles that have passed through one or more stages of production, such as bar iron, steel, leather, partially dressed stone, lumber, cloth, partially constructed furniture, etc. Opposite "Mill supplies" give the cost of oil, waste and other supplies consumed in the running of machinery.

INQUIRY 8.—*Miscellaneous Expenses:* All items of expense incident to the business not accounted for under Inquiries 5 and 7 must be reported here. Do not include commissions or expenses of sales department or any portion of the freight reported under Inquiry 7 as paid on materials.

INQUIRY 9.—*Goods Manufactured:* Give the value or price charged at shop or factory, not including commissions, or expenses of sales department, and account for all products, including by-products. *The principal products must be enumerated and separate values given for each.* Quantities should be given when possible, and the unit of measurement stated, as "pounds," "tons," "bushels," "feet," "yards," etc. If there are products other than those for which a separate value can be given, their total value should be reported opposite "All other products." The amount received for odd jobs or work done must be given as "Custom work and repairing."

Immediately on receipt of the filled and returned schedules they were examined to see if all of the questions asked had been answered and in the proper form. Next, the returns were analyzed to ascertain if they contained duplications in the entries of money or material; then costs of material and labor were inspected and checked by information obtained from a large number of reliable sources having due regard to the industry under consideration and the locality where the operations were carried on. Then the materials and products were compared as to kind and amount, to ascertain if any inconsistency existed, and these were checked by reliable data at hand. In the industry with which I was charged, the methods of stochiometry were employed to ascertain theoretical yields and then the proper margin for losses in yields was applied and these compared with data from other sources. The returns of capital, miscellaneous expenses, months in operation, employees and wages were investigated by previously agreed upon methods which were issued as instructions by the office to all in any way connected with the examination of schedules.

When errors were discovered, the attention of the special agent who "took" the schedule, or of the person who furnished the information, was called to the matter by correspondence, the particular errors and their character being pointed out. We were aided in making this explanation by the fact that two copies of the schedule were given to each establishment to be filled, one of which was to be retained

by the person giving the information and the other forwarded to this office, and by these means a large number of the schedules were perfected. Where this was not done, and the matter was of sufficient importance, a personal visit would be made to the establishment or several establishments of that class, where operations could be studied at close range and the persons conducting the business conferred with directly. This I found to be a most satisfactory method of procedure, for I received the most courteous treatment, was given every facility for procuring information and received the assurance of the manufacturers, when they definitely understood what it was sought to accomplish, that the project met with their complete approval, and, if accomplished, would be greatly to their benefit. When, however, these means of directly securing information were exhausted without avail, then indirect sources were drawn upon. In my own experience I can recall but one instance where the responsible official of an enterprise of magnitude persistently (and it must be said intemperately) refused to give the information required. Yet his obstinacy availed him nothing, as his broader-minded associates in the enterprise took a different view of the matter.

The investigation of the schedules for the chemical and allied industries was especially difficult, because of the large number of instances in which material produced in an establishment was used in further manufacturing operations in the same establishment, and to the further fact that in many cases part of the material consumed appeared as a by-product which was regained and reused in subsequent operations. The separation of this material was essential, not only to prevent duplication, but, also, to present the true condition of collateral manufactures. Thus, in the fertilizer manufacture some manufacturers purchase the sulphuric acid with which to make their superphosphate, while others have sulphuric acid plants in which they make the sulphuric acid which they subsequently consume. In the manufacture of explosives the same conditions hold true for nitric acid, while here also the sulphuric acid is regained and used over. Evidently, to present a true state-

ment of the condition of either of these acid industries these data must be analyzed and separated.

These were some of the perplexities attending the work, but the most unsatisfactory item of all to deal with was capital. In relation to this matter Superintendent Walker said, in the census report of 1870: "The census returns of capital invested in manufactures are entirely untrustworthy and delusive. The inquiry is one of which it is not too much to say that it ought never to be embraced in the schedule of the census, not merely for the reason that the results are, and must remain, wholly worthless, the inquiry occupying upon the schedules the place of some technical question which might be made to yield information of great value, but also because the inquiry in respect to capital creates more prejudice and arouses more opposition to the progress of the enumeration than all the other inquiries of the manufacturing schedules united. It is, in fact, the one question which manufacturers resent as needlessly obtrusive, while at the same time it is perhaps the one question in respect to their business which manufacturers, certainly the majority of them, could not answer to their own satisfaction, even if disposed. No man in business knows what he is worth—far less can he say what portion of his estate is to be treated as capital. With respect, indeed, to corporations having a determinate capital stock, the difficulty of making a correct return in this particular becomes very much reduced; yet, even here, the difference caused by returning such capital stock at its normal value on the one hand, or at its actual selling price on the other, whether above or below par, might easily make a difference of 50 or 75 per cent. in the aggregate amount of capital stated for any branch of industry.

"Where, however, business is carried on outside of incorporated companies the difficulty of obtaining even an approximate return of the inquiry itself, irrespective of the reluctance of manufacturers, becomes such as to render success hopeless. So numerous are the constructions possible, and even reasonable, in respect to what constitutes manufacturing capital, that any thing like harmony or consistency

of treatment is not to be expected by a large body of officials pursuing their work independent of each other. The superintendent is free to confess that he would be puzzled to furnish a definition (fit for use by practical enumerators) of manufacturing capital, or even in a single case, with complete access to the books of a manufacturing establishment conducted by two or more partners, and with the frankest exhibit of assets, both of the firm and of the individual members thereof, to make up a statement of the capital of the concern in respect to which he would feel any assurance. When to such difficulty in the nature of the subject is added the reluctance of manufacturers to answer an inquiry of this character, it may be fairly assured, in advance of any enumerations, that the results will be of the slightest possible value."

This opinion has been voiced by many competent persons on many occasions, but the information is still required by law.

Taking the manufacturing schedules as a whole, the quantity of obviously erroneous information received on the first returns was appalling. Many of the schedules showed an obvious misapprehension of the significance of the questions asked; some of the schedules revealed upon their face the intention to mislead and deceive the Census Office. In my personal experience these usually emanated from unwise subordinates, who thought thus to protect the interests with which they were charged. On bringing these returns to the attention of the principals, they expressed regret, tendered apologies, supplied schedules perfected in every detail and rendered every possible assistance. In fact, as stated, after manufacturers became convinced that we were handling the matter intelligently and bid fair to obtain results that would be of value without jeopardizing personal interests, they gave us the fullest assistance. Several furnished a transcript of the statement of their business for the prior six months or year. Others drew from their books a detailed statement of every kind of material purchased by them during the census year, with quantities and costs. Others supplied wage lists; others, precise information as to processes.

In the study of processes and products use was made for the first time in census work of the rich store of information accumulated in our patent archives, and a résumé of the U. S. patents is appended to the report on chemicals and allied products.

During the revision of the schedules Dr. Chatard, my associate, and I perfected a system for carding the returns on the schedules for chemical manufactures, which enabled us to promptly release the perfected schedules for the use of the tabulation division, while retaining the data for the analysis preliminary to the preparation of the report. By this means an additional check was put upon the tabulations, and the scheme had the additional merit that it compelled the closest scrutiny of the returns and thereby prevented items from being overlooked that might otherwise have escaped attention.

There was printed for the Division of Manufactures, 1,250,000 general schedules and 1,037,500 special schedules, or 2,287,500 in all. There were received and examined over 771,000 schedules, and of these 530,470 general schedules and 113,588 special schedules were perfected and tabulated. The publication of the results of the year ending June 1, 1900, began in a preliminary way in March, 1901, with a set of bulletins of which 105 were issued, and the final report was completed and published June 1, 1902, within the time limit set by law. The time required by previous censuses to accomplish this result is shown in the following table:

TIME INTERVENING BETWEEN COLLECTION AND PUBLICATION OF STATISTICS OF MANUFACTURES.

Date of census.	Date when final report was printed.
1850	1859
1860	1865
1870	1872
1880	1883–1888
1890	1895
1900	1902

The report of the census of manufactures for 1900 is published in four quarto volumes, containing 4,237 pages, 1,796 tables, and 114 maps, charts and illustrations. These

volumes are numbered 7 to 10 of the reports of the twelfth U. S. census. Volume 7, or Part I of the report, is devoted to a discussion of the plan, method and scope of the twelfth census of manufactures, summary and analysis of results, urban manufactures, power employed in manufactures, description of general tables and statistics for the United States by industries. There is also included here copies of all the schedules used, a record of the cities and towns canvassed by special agents, the instructions to these agents, the instructions for editing the schedules of manufactures and the classification of the industries which was adopted.

Volume 8, or Part II of manufactures, is devoted to separate reports on each State and Territory. The collaboration of expert local authorities was secured in the preparation of these reports, and they are therefore not only filled with statistical data of immediate local interest, but they are replete with historical information, which must be ever invaluable to those who study our industrial development.

Volumes 9 and 10, Parts III and IV, are given up to the special reports on selected industries. The industries selected for treatment are: Combined textiles; cotton, wool and silk manufactures; flax, hemp and jute products; dyeing and finishing textiles; the manufacture of clothing; collars and cuffs; buttons; cotton ginning; flouring and grist-mill products; slaughtering and meat packing; cheese, butter and condensed milk as produced in factories; canning and preserving; oleomargarine; salt; beet sugar; rice; starch; cottonseed products; alcoholic liquors; manufactures of tobacco; manufactured ice; leather; boots and shoes; rubber boots and shoes; leather gloves and mittens; the lumber industry; clay products; glass; turpentine and rosin; paper and pulp; printing and publishing; iron and steel; tin and terne plate; electrical apparatus and supplies; shipbuilding; locomotives; cars; carriages and wagons; bicycles; agricultural implements; metal-working machinery; motive-power appliances; sewing-machines; needles and pins; typewriters; musical instruments; watches and watch cases; pens and pencils; chemicals and allied products; petroleum

refining; coke; gas; the utilization of wastes and by-products; and patents in relation to manufacture. In the preparation of this paper I have drawn freely on these volumes with which to supplement my knowledge of the work as gained in a part of the field. This enormous undertaking was accomplished in 1,100 working-days with a force of 412 clerks, most of whom were previously untrained in census methods, at a cost of $1,211,952.87.

From the results it appears that the aggregate value of the products of all manufacturing industries for the census of 1900 is $13,004,400,143. A comparison of this result with that of previous censuses is given in the following table:

AGGREGATE VALUE OF MANUFACTURES.

1810	$198,613,471
1850	1,019,106,616
1860	1,885,861,676
1870	4,232,325,442*.
1880	5,369,579,191
1890	9,372,437,283
1900	13,004,400,143

* Based on paper currency.

First in rank among the separate industries is iron and steel, with $803,968,273 of gross products; second is slaughtering and meat packing, with $790,252,586 of gross products. Foundry and machine-shop products, lumber and timber products, flouring and grist-mill products follow in close order, each having above $500,000,000 of gross products.

First in rank among the great cognate groups of industries is food and kindred products, with an output of gross products of $2,277,702,010; second is iron and steel and their products, with gross products amounting to $1,793,490,908. Following these are textiles, lumber and its manufactures, and leather and its finished products, forming the first five of the great groups. We might continue to draw from this enormous collection of statistics information going to show the wonderful condition of industrial activity to which this country has attained; a condition which justifies its pre-eminent position as a world-power.

Although the general scope of the manufacturing census

of 1900 was limited by law to an exact parallel of the census of 1890, so far as the schedule was concerned, it has, nevertheless, been possible to introduce several important modifications in the presentation of the statistics, which mark a distinct advance in this branch of the census work. The most striking of these improvements may be summarized as follows:

(1) The treatment of each State and Territory as a distinct entity—the statistics of the State being presented as a whole, and all its cities and counties being presented together in one volume, instead of being published in two separate volumes, as was the case in 1890. Accompanying the statistics of each State is a brief description of the origin and character of its leading manufacturing industries.

(2) A division of the statistics into those for the hand trades and those for manufactures proper, and a separate presentation of the statistics of each of these different forms of industry.

(3) A division of industries into fifteen cognate groups on the basis of the materials used, or similarity in use of products, thus permitting a proper estimate of the relative importance of each of the general branches of industry.

(4) A marked increase in the number of industries for which special reports were made. There were six such special reports included in the census of 1880, twenty in the census of 1890, and fifty-nine in the census of 1900. All of these reports at the present census have been accompanied by considerable historical and descriptive matter. This is the direction in which it has seemed most feasible to increase the general value and usefulness of a census of manufactures.

(5) The grouping of manufacturing establishments by the number of hands employed in each, and the further separation of those which use power from those which do not. Only by bringing together figures presented in different parts of the volume can the student of the census of 1890 make this comparison between establishments using power and those not using it.

(6) The elimination of duplications in the statistics which

show the gross value of products. It has not been possible to carry this improvement so far as is deemed desirable and necessary, but a great step in advance has been taken.

(7) The presentation of statistics for establishments according to the character of their organization.

(8) The extension of the function of the census into the field of statistical interpretation, without attempt or intention to enter the peculiar field of the economist or the sociologist.

The experience of the office has been a tentative one; a feeling of the way from census to census with distinct progress visible at each. This progress has necessarily extended the work beyond the mere gathering and presentation of statistical data into the field of intelligent interpretation; and as this function of a manufacturing census enlarges the work of the statistician, it brings him into constantly closer touch with the work of the economist and the sociologist. Nevertheless, the line of demarcation remains a clear one, the function of the Census Office being to ascertain the facts, and to throw all possible light upon their interpretation and upon the limitations surrounding the use of the figures. It is the function of the economist and the sociologist, observing these limitations, to draw conclusions from the data presented. But the statistician, in order to perform his part of the work, is entitled to go to all outside sources for information which will aid in the illumination and interpretation of the statistics themselves. This has been done at the present census to a degree not hitherto attempted.

In a paper read by Chief Statistician North before the National Association of Manufacturers on April 25, 1900, after bespeaking the sympathy and co-operation of its members in the undertaking just launched, and pointing out the advantages that would accrue from a successful issue, said:

"No census of manufactures yet taken has been free from very grave faults; but each succeeding census has been a vast improvement on its predecessor. Those in charge of the present work will be unequal to their opportunity, if they do not succeed in making the twelfth census the best in the series—a statistical photograph of the produc-

tive energies of the nation, which shall focus an industrial wealth and resource undreamed of in the past, as our opening vision of the twentieth century." The work is now ended; its results are at command, and you can all determine if the promise has not been fulfilled.

Book Notices.

International Catalogue of Scientific Literature. First annual issue. Published for the International Council by the Royal Society of London. D. Chemistry, Part I. London: Harrison & Sons. 8vo, 468 pp. Paper.

The International Catalogue of Scientific Literature is an outgrowth of the *Collection of Scientific Papers*, published by the Royal Society of London. The suggestion to make such a catalogue is credited in the preface of the present work to Professor Henry, of the Smithsonian Institution, who brought the subject up at a meeting of the British A. A. S., at Glasgow, in 1855. The possibility of preparing a complete index of current scientific literature by international co-operation was taken into consideration by the Royal Society about the year 1893. As it was evidently beyond the means of this body to carry out the plan, conferences with scientific authorities of other countries were held, and in June, 1900, sufficient guarantees were obtained to warrant the beginning of the work. The material published is contributed by regional bureaus, which, so far, have been established in thirty countries. Each complete annual issue will cost £18 and consist of seventeen volumes. Single volumes will be sold at prices ranging from 10 to 35 shillings. The volume before us is priced at 21 shillings.

It is not necessary to speak of the value of such a publication. Every active worker in science knows the use of it, and it is fortunate that the financial aid necessary to its production has been obtained. Attention is called in the preface to the advisability of journals assisting the bureaus, by indexing each paper at the time of publication. It is to be hoped that editors and authors will co-operate actively along this line, so as to promote this most valuable enterprise.

The literary character and mechanical execution of the volume before us are excellent. H. L.

Elementary Chemistry. By Robert Hart Bradbury, A.M., Ph.D. New York: D. Appleton & Co. 1903. 329 pages; and Part II, *Experimental Work*, to accompany the text, 157 pages.

Among the numerous chemical texts for students in secondary schools that have been recently published, this book is undoubtedly one of the best and in some respects the most original.

The author's program is clearly stated in the preface, and a careful perusal

of the book by the reviewer has satisfied him that the plan has been logically and successfully carried out.

It has been a genuine pleasure to read this independent account of the state of elementary chemistry as it exists *to-day*, by one who is not only thoroughly familiar with the literature of the subject, but who is also an experienced teacher.

The lucid, logical, and, withal, attractive manner of presentation cannot fail to make this manual an excellent and popular text for beginners, as well as profitable reading for more advanced students.

The introductory chapters are devoted to the familiar subjects of water, common salt, and atmospheric air, the discussion of which affords opportunities for explaining and developing the fundamental principles of chemical science. A very noticeable feature of the book is the easy and natural way in which the recent achievements of physical chemistry are made part of the foundation which is laid here; indeed, those paragraphs which deal with solution, acids, bases, and salts, ions, catalysis, speed of reactions, and the like, must be regarded as the gems of the book.

A fine balance is maintained throughout between the systematic and the historical methods of treatment. The former secures economy of effort on the part of the student, enabling him to master a great wealth of material; the latter, judiciously introduced, keeps his interest awake. It is only at the close of the text that the natural classification of the elements (the periodic law) and an historical sketch of chemistry are given. Both chapters are very readable.

The laboratory exercises, forming Part II, are, for the most part, those which are included in similar manuals. They are well selected and arranged, and the directions are very carefully given, the precautions necessary to insure success and avoid dangers being explicitly stated. The questions and problems at the end of each chapter in Part II are well adapted to promote the student's knowledge and interest.

The typography and illustrations are in harmony with the character of Dr. Bradbury's admirable production. H. F. K.

The Manufacture and Properties of Iron and Steel. By Harry Huse Campbell, General Manager of the Pennsylvania Steel Company. 8vo, pp. xxix + 862. New York and London: Engineering and Mining Journal. (Price, $5.co.)

The first edition of Mr. Campbell's work on this subject was favorably noticed in these pages several years ago. The present work, ostensibly a second edition, is in reality so completely rewritten and so enlarged by the introduction of new material, that it constitutes in reality a new book.

Among the many new features added to the present work are the divisions on the blast furnace, the open-hearth, and the use of fuels, while the pig and ore process, as well as the Bertrand Thiel and Talbot methods, are fully discussed. A new departure is the description of each separate important iron-producing district in the world, and no other publication has thus far attempted to cover this field. W.